Induced innovation, the distributive cycle, and the changing pattern of labour productivity cyclicality: a SVAR analysis for the US economy

Stamegna, Marco

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Marco Stamegna*

Abstract The empirical literature on induced technical change has explored the long-run relationship between real wages and labour productivity but still lacks an explicit treatment of the implications of the wage-productivity nexus for the business cycle. The present paper aims to fill this gap. By employing a four-dimensional structural vector autoregressive (SVAR) model for the US economy (1948-2019), we test an extended version of the Goodwin model that includes aggregate demand and decomposes the labour share into real wages and labour productivity. This paper adds to the existing literature in some respects. First, it contributes to the induced innovation literature, by showing that wage shocks have positive and persistent effects on labour productivity at business cycle frequencies. Second, it adds to the debate and empirical evidence on the distributive cycle. Impulse response functions show that, even when decomposing the labour share, empirical evidence supports the Goodwin pattern, although the profit-led regime turns out to be driven more by technology than distributive shocks. Finally, we address two relevant cyclical stylized facts of the US economy: since the mid-1980s, the procyclical pattern of labour productivity has vanished, and real wages have no longer been correlated with employment over the business cycle. We explore the hypothesis that the two changes are linked. In light of the theory of induced innovation, we argue that the decline in the cyclical correlation between output and labour productivity can be explained by a lessened incentive to invest in labour-saving innovations due to missing wage growth in the upturn of the business cycle. Impulse response functions qualitatively support this intuition.

Keywords Labour productivity, endogenous technical change, income distribution, SVAR

JEL classification E12, E24, E25, E32

* Department of Economics and Statistics, University of Siena, Piazza San Francesco 7, Siena, Italy; email: marco.stamegna@student.unisi.it

1. INTRODUCTION

The procyclicality of labour productivity has conventionally been considered a defining feature of the business cycle in macroeconomic literature. Mainstream authors have long debated the source of this stylized fact. The New Keynesian explanation relies on labour hoarding, that is, variation in labour utilization over the business cycle, motivated by the presence of hiring and firing costs along the extensive margin of labour adjustment. By contrast, the proponents of the Real Business Cycle theory argue that procyclical labour productivity is the result of a business cycle driven by exogenous technology shocks. Thus, in mainstream economic literature, explaining the procyclical pattern of labour productivity has progressively become an empirical test for competing models of the business cycle (Basu, 1996; Basu and Kimball, 1997; Galí, 1999; Basu and Fernald, 2001; Basu, *et al.*, 2006).

More recently, the issue of procyclical labour productivity has also been addressed in non-orthodox economic literature. In this context, it has been invoked for its alleged implications for the relationship between income distribution and economic activity, namely for the demand and distributive regimes of the economy. Neo-Kaleckian authors argue that neo-Goodwinian findings of profit-led demand and profit-squeeze distribution regimes are the result of a failure to consider procyclical variations in labour productivity. On the empirical ground, they contend that if aggregative estimates of the demand regime were allowed to account for procyclical productivity, empirical evidence would not any longer support the Goodwin pattern (Lavoie, 2017; Cauvel, 2019; Fiebiger, 2022).

Since the mid-1980s, however, the procyclical pattern of US labour productivity has vanished, and output per worker and output per hour are no longer positively correlated with output or labour input. Productivity has shifted from strongly procyclical to roughly acyclical or weakly countercyclical relative to output, and from weakly procyclical to strongly countercyclical relative to employment and hours worked (Stiroh, 2009; Galí and Gambetti, 2009; Barnichon, 2010; Gordon, 2010; Fernald and Wang, 2016; Galí and van Rens, 2021). The changes in cyclical comovements among productivity, output, employment, and hours worked in the Euro area and other OECD countries have shown a similar pattern (Ohanian and Raffo, 2012; van Rens, 2012; Conti, *et al.*, 2019).

The decline in the cyclical correlation between output and labour productivity has been accompanied by another change in a key cyclical stylized fact: real wages appear to have become less responsive to fluctuations in economic activity and employment – namely, the real wage Phillips curve has become "flatter" (Roberts, 2006; Kuttner and Robinson, 2010; Galí and Gambetti, 2019). The transition of the US economy to the so-called Great Moderation period has indeed been marked by increasing labour market deregulation, in the form of deunionization, diffusion of part-time and temporary jobs, and reduction in workers' living standards, which have made it more difficult for workers to claim for higher wages in the upturn of the business cycle (Setterfield, 2005; 2021; Ratner and Sim, 2022).

This paper proposes a novel explanation for the change in the cyclical pattern of US labour productivity in light of the theory of distribution-induced technical change. It explores the hypothesis that the decline in the cyclical correlation between output and labour productivity is linked to the missing wage growth resulting from the flattening of the real wage Phillips curve. Thus, it argues that the reduced procyclicality of labour productivity is partially explained by a lessened incentive to invest in labour-saving innovations due to missing wage growth in the upturn of the business cycle. As real wages fail to sufficiently respond to labour market tightness, an increase in the level of economic activity does no longer raise labour productivity. The argument is briefly contrasted with competing explanations focusing on increasing labour market flexibility in the New Keynesian literature, which do not appear to be in line with some cyclical stylized facts of the US economy.

By employing a four-dimensional structural vector autoregressive (SVAR) model, I test an

extended version of the Goodwin model that includes aggregate demand and decomposes the labour share into real wages and labour productivity. A non-recursive structure derived from Goodwinian theory is imposed on the matrix of contemporaneous effects. I consider two different periods, the post-war period (1948-1984) and the Great Moderation (1985-2019), in order to illustrate the changes in the properties of the US business cycle.

Thus, this paper adds to the existing literature in some respects. First, it contributes to the literature on induced technical change, by investigating the wage-productivity nexus at business cycle frequencies. Impulse response functions show that wage shocks have a positive and persistent effect on labour productivity in both periods, in accordance with the predictions of the theory.

Second, it adds to the debate and empirical evidence on the distributive cycle. I find that, even when decomposing the labour share into real wages and labour productivity, the US post-war period shows a profit-led demand and employment regime and a profit-squeeze distribution regime at business cycle frequencies. This result is robust to different measures of economic activity and labour market tightness. Moreover, controlling for procyclical productivity turns out to be irrelevant for evidence to support the existence of the distributive cycle, since allowing for a contemporaneous effect of demand on productivity does not fundamentally alter the main results. However, some theoretical questions remain open on the source of the profit-led regime, which appears to be largely driven by movements in labour productivity rather than in real wages.

Finally, this paper contributes to the literature on the change in the cyclical behaviour of US labour productivity. It claims that – together – the profit squeeze and induced technical change are an additional source of procyclicality in labour productivity. Differently from cyclical fluctuations in labour productivity implicit in Okun's Law, which are a mere artifact reflecting variable factor utilization, distribution-induced cyclicality in labour productivity reflects changes in the true state of technology of the economy over the business cycle. The stronger the decline in the profit share in the upturn of the business cycle, and the stronger the capitalists' incentive to preserve their profit margins by adopting labour-saving innovations, the more positive the cyclical comovements between output and labour productivity. Thus, this paper argues that the breakdown of the profit squeeze distribution regime in the Great Moderation, in the form of a flattening of the real wage Phillips curve, may account for part of the decline in the procyclicality of labour productivity. Impulse response functions qualitatively support this view.

The remainder of this paper is organized as follows. Section 2 provides an extensive discussion of the related literature and the main contributions of this paper. Section 3 documents some stylized facts about the US post-war period and the Great Moderation, with a special focus on the changing patterns of labour productivity cyclicality and employment-wage correlation. Section 4 derives the basic hypotheses that motivate this analysis. Section 5 describes data sources and the theoretical premises of our identification strategy. Section 6 discusses the main findings derived from impulse response functions, forecast error variance decomposition, and the estimated structural coefficients of the model. Section 7 shows that the main results are robust to different model specifications. Section 8 then concludes.

2. RELATED LITERATURE

This paper is related to the recent empirical literature on distribution-induced innovation. The theory of induced technical change states that an increase in real wages, relative to labour productivity, fosters the adoption of labour-augmenting innovations. In the classical and Marxian approach to induced innovation, labour-augmenting technical change is thought of as a weapon of the capitalist class in the capital-labour conflict, as it allows capitalists to defend their profit margins

in the face of rising labour costs (Foley, 2003; Julius, 2005; Rada, 2012; Tavani, 2012; 2013; Zamparelli, 2015; Tavani and Zamparelli, 2018; Foley, *et al.*, 2019). This theory implies a classical narrative on secular stagnation relating the slowdown in capital accumulation and labour productivity growth in advanced economies to the decline in the labour share of income (Petach and Tavani, 2020; Barrales-Ruiz, *et al.*, 2021; Luzuriaga and Tavani, 2021; Rada, *et al.*, 2021).

Some recent empirical works have tested the main predictions of the theory of induced innovation. Marquetti (2004) uses a vector error correction model to identify the long-run relationship between real wages and labour productivity in the US economy. He finds that the two series are cointegrated, with unidirectional Granger causality going from real wages to labour productivity. De Souza (2017) extends this methodology to a panel of industries and developed and developing countries and finds evidence of cointegration and bidirectional Granger causality between real wages and labour productivity, providing empirical support to distribution-induced innovation and long-run stationarity in the labour share. Dávila-Fernández (2020), by applying a panel vector autoregressive model to a sample of OECD countries, finds that positive shocks to the ratio of labour to capital share raise labour productivity growth, in line with the predictions of models of endogenous technical change based on an innovation possibility frontier (Kennedy, 1964; Samuelson, 1965).

Other studies, albeit not explicitly related to the theory of induced technical change, give empirical support to its central argument of a positive long-run association between the labour share and output growth. Charpe, *et al.* (2019) apply wavelet analysis to the UK, France, and the US economies in order to investigate the relationship between the labour share and economic growth across different time frequencies. They find that the labour share depresses growth at low frequencies but leads growth in the long run. Li and Mendieta-Muñoz (2020), by using a time-varying parameter model, provide evidence of a decline in the natural rate of growth in G7 countries that started much before the Great Recession and was mainly driven by a fall in the technical progress component – a result that can be consistent with the theory of induced innovation. Kiefer, *et al.* (2020) estimate the potential output rate of growth for the US economy conditional on the dynamic interaction between the labour share and economic activity at the business cycle level and, even without making a specific causal claim, conclude that the labour share and output gap have shared a downward trajectory over decades.

Second, this paper is related to the growing empirical literature on the distributive cycle. Building on the original Goodwin (1967) model of the growth cycle and the more flexible neo-Goodwinian model by Barbosa-Filho and Taylor (2006), the theory of the distributive cycle predicts counterclockwise cycles in the employment-labour share plane and the utilization-labour share plane, as a result of the combination of a profit-led demand and employment regime and a profit-squeeze distribution regime at business cycle frequencies. The original framework has been extended to incorporate a counterclockwise cycle in the utilization-employment plane of the kind observed in the US and other OECD countries (Zipperer and Skott, 2011; von Arnim and Barrales, 2015; Araujo, *et al.*, 2019).

While original empirical studies (e.g. Desai, 1984; Harvie, 2000) tried to find Goodwin cycles in the long-run waves of employment and distribution, the more recent empirical research looks at the short-run patterns in economic activity and distribution around a long-run trend determined by structural and institutional changes (Mohun and Veneziani, 2008) and makes extensive use of the vector autoregressive (VAR) methodology.[1]

Barbosa-Filho and Taylor (2006) employ a reduced-form VAR to estimate the slopes of the distributive curve and the effective demand curve for the US economy. Their findings – a positively sloped distributive curve and a negatively sloped effective demand curve – empirically support the existence of the Goodwin pattern in the utilization-distribution plane. Kiefer and Rada (2015)

[1] For an extensive review of the theoretical debate and empirical evidence on the distributive cycle, see Barrales-Ruiz, *et al.* (2021).

estimate a panel VAR for some OECD countries and find evidence of a counterclockwise cycle in the utilization-labour share plane around a downward trend in both variables. Araujo, *et al.* (2019) show that empirical evidence in favour of the Goodwin pattern in the employment-distribution plane for the US economy is robust to the use of different filtering techniques.

Barrales-Ruiz, *et al.* (2021) claim that recursive VAR models based on classical-Keynesian theory should always allow the labour share to have a contemporaneous effect on the economic activity variable, but not the other way around, as this "standard ordering" reflects a rapidly adjusting goods market and a slowly adjusting labour share. These identifying restrictions support the Goodwin pattern for the US in both the employment-distribution plane and the utilization-distribution plane. However, they find that even the "reverse ordering" confirms the profit-squeeze distribution regime. Basu, *et al.* (2013) employ a three-dimensional VAR to test an extended version of the Goodwin model for the US including fixed investment and show that the finding of a cyclical profit squeeze does not depend on the ordering of the variables. The augmented six-dimensional VAR by Basu and Gautham (2019), who apply the recursive identification strategy proposed by Christiano, *et al.* (1999), confirms that adverse shocks to the labour share have a positive impact on utilization, employment, and capital accumulation at business cycle frequencies.

This paper adds to the more recent empirical research using SVAR methodology, in which a non-recursive structure derived from neo-Goodwnian theory is imposed on the matrix of contemporaneous effects. Santetti (n.d.) tests two extended versions of the Goodwin model, by imposing non-recursive restrictions on the A matrix of an AB-type SVAR model[2] and using the cyclical trajectories technique for impulse responses presented in Nikiforos, *et al.* (2021). The first model is a four-dimensional SVAR model including output, labour share, employment, and investment. The second model is a five-dimensional SVAR model splitting investment into its residential and nonresidential components. Cyclical trajectories derived from the two models support neo-Goodwinian findings of profit-led demand and employment, profit-squeeze distribution, and the leading role of investment over the business cycle. Mendieta-Muñoz, *et al.* (2021) estimate a four-dimensional SVAR in output, real wages, unemployment, and labour productivity with a non-recursive strategy to identify the structural innovations driving the labour share in the post-war era and in the neoliberal era of the US economy. Albeit not explicitly focusing on the demand and distributive regimes, they motivate the restrictions on the A matrix on the basis of neo-Goodwinian theory.

On a theoretical ground, some authors have integrated the induced innovation hypothesis into the Goodwin model and explored the implications for the dynamic stability properties of the growth cycle. The introduction of induced innovation makes the equilibrium point a stable focus (Shah and Desai, 1981; van der Ploeg, 1987; Foley, 2003). However, neither the literature on induced innovation nor the literature on the distributive cycle have explored the implications of the wage-productivity nexus for the business cycle on the empirical ground. The purpose of this paper is to fill this gap. By decomposing the labour share into real wages and labour productivity and apply filtering techniques, I show that the distribution-induced innovation mechanism starts operating at business cycle frequencies. Thus, part of the changes in labour productivity over the business cycle are in fact the result of wage-led technology shocks, reflecting the capitalists' incentive to invest in labour-saving innovations in response to rising real wages.

The decomposition of the labour share allows addressing the issue of the implications of cyclical variation in labour productivity for the demand, employment, and distributive regimes of the economy. Indeed, an increase in the labour share can be caused either by an increase in real wages or by a decrease in labour productivity. Thus, in the context of a decomposed labour share, a demand regime is profit-led if a distributive or technology shock raising the labour share has a negative effect

[2] See Lütkepohl (2005, Section 9.1).

on economic activity at business cycle frequencies,[3] and a distributive regime is profit-squeeze if a positive shock to the economic activity raises real wages and/or reduces labour productivity.

More recently, the issue of procyclical labour productivity has been invoked by supporters of wage-led growth to question the existence or the drivers of the Goodwin pattern. Fiebiger (2022) lists procyclical variation in labour productivity due to overhead labour (i.e. labour employed in proportion to productive capacity, as opposed to "direct labour" employed in proportion to actual output) among the six cyclical stylized facts for which neo-Goodwinian theory fails to offer a consistent explanation. Lavoie (2017) claims that the negative cyclical comovements between economic activity and labour share observed in the first phase of booms and recessions reflect procyclical productivity rather than profit-led demand. Thus, in his view, the Goodwin pattern is the result of a combination of procyclical profit share and external drivers of output rather than of cyclical fluctuations in the reserve army of labour driven by profit-led capital accumulation. His argument implies that empirical studies that fail to account for procyclicality in labour productivity could be biased towards finding profit-led demand and mistakenly be interpreted as supportive of the Marxian view of the business cycle. Cauvel (2019) estimates a three-dimensional recursive VAR in capacity utilization, real wages, and labour productivity for the US under different variable orderings. He finds that only the standard ordering confirms profit-led demand and profit-squeeze distribution. Results based on identifying restrictions that demand contemporaneously affects labour productivity no longer support the Goodwin pattern.

In the baseline model of this paper, demand only has a lagged effect on labour productivity, as in standard empirical works motivated on the basis of neo-Goodwinian theory. As a robustness check, I estimate an alternative model specification allowing for a contemporaneous effect of demand on productivity. Both models lead to qualitatively similar results, thus calling into question the relevance of procyclical labour productivity for empirical evidence to support the existence of the Goodwin pattern. However, irrespective of the chosen identification strategy, the profit-led regime appears to be largely driven by technology rather than distributive shocks – a result which opens relevant theoretical questions.

Finally, this paper relates to the debate on the decline in the cyclical correlation of US labour productivity with output and employment. New Keynesian authors have proposed several explanations for these changes, broadly falling into two categories: (i) changes in the volatility of demand shocks relative to technology shocks, and (ii) changes in the response of labour productivity to demand shocks, mainly (but not only) as a result of changes in firms' labour hoarding behaviour due to increasing labour market flexibility.[4]

The first explanation relies upon the argument that, in DSGE models with sticky prices and labour market frictions, demand shocks and technology shocks trigger opposite short-run comovements in employment and productivity. Positive demand shocks increase output, employment and – via Okun's Law – labour productivity. By contrast, following a positive technology shock, sticky prices prevent aggregate demand from increasing as much as productivity. As firms use less labour to produce the same amount of output, positive technology shocks generate negative cyclical

[3] The definition is similar to the one in Nikiforos and Foley (2012). However, in their analysis of the implications of a U-shaped distributive curve, distributive and technology shocks lead to exogenous shifts in the distributive curve, and their definition of profit-led economy refers to the steady-state effects of exogenous changes in income distribution. In this paper, the focus is on the impact of distributive and technology shocks on economic activity at business cycle frequencies, which determines the *slope* of the demand curve.

[4] A detailed discussion of New Keynesian explanations for the changes in the cyclical pattern of US labour productivity is beyond the scope of this paper. In this section, I limit myself to discuss the hypotheses that can be easily compared with the central argument of the paper. Other explanations include increased importance of reallocative shocks relative to aggregate shocks (Garin, *et al.*, 2018), changes in the structure of labour compensation (Nucci and Riggi, 2011), increased persistence of technology shocks, and shifts in the structure of the economy towards the service sector (Wang, 2014). For an extensive review of the evolution of the consensus on the cyclical behaviour of productivity, as well as the main hypotheses for the vanishing procyclicality in the New Keynesian literature and empirical evidence in favour and against each of them, see Fernald and Wang (2016).

comovements between employment and productivity (Basu, 1996; Galí and Gambetti, 1999). Thus, the decline in the procyclicality of labour productivity is ascribed by some New Keynesian authors to the diminished importance of demand shocks relative to technology shocks, with the former having become less volatile than the latter in the Great Moderation period (Galí and Gambetti, 2009; Barnichon, 2010; Daly, *et al*, 2015). This change in relative volatility is often attributed to the improved conduct of monetary policy, which is supposed to have become more effective in accommodating changes in potential output resulting from technology shocks (Galí, *et al.*, 2003; Galí and Gambetti, 2009).

The second explanation posits that labour productivity has become less procyclical conditional on demand shocks, mainly as a result of increased labour market flexibility, which has made it less costly for firms to hire and fire workers in response to fluctuations in demand. The labour market argument rests on the assumption that firms face a trade-off between adjusting the extensive margin (i.e. the number of employees) and adjusting the intensive margin (i.e. hours per worker or labour effort) in the upturn and downturn of the business cycle. Increased labour market flexibility, by reducing adjustment costs along the extensive margin, causes firms to rely more on adjusting the extensive margin relative to the intensive one in the face of changes in demand. As a result, the relative volatility of employment increases and observed labour productivity varies less positively over the cycle (Barnichon, 2010; Daly, *et al*, 2015; Galí and van Rens, 2021).

This explanation suffers from some shortcomings. Indeed, increased labour market flexibility may affect both the extensive and the intensive margins of adjustment. The labour market argument rests on the assumption that labour market reforms have made the cost of adjusting employment fall more than the cost of adjusting hours per worker, which is not clear a priori. An implication is that employment should have become more volatile relative to hours per worker in the Great Moderation period. However, empirical evidence on this point is at best inconclusive.[5] Wang (2014) examines the volatility of employment and hours per worker using industry-level data for the US. She finds that both margins of adjustment have become more volatile relative to output, but employment has become less, rather than more, volatile relative to hours per worker in most of the industries. Furthermore, the change in the cyclicality of labour productivity appears not to be correlated with the change in the relative volatility at the industry level. Van Rens (2012) investigates the importance of intensive and extensive margins of adjustment in European countries as compared to the US. He finds that, despite the evidence that labour market frictions are higher in European countries, adjustments along the intensive margin are not significantly more important in Europe than in the US. In the next session, I document some stylized facts about the US economy that do not appear to support the labour market argument along New Keynesian lines.

This paper proposes a novel explanation along induced innovation lines, linking the decline in the cyclical correlation of labour productivity with output and employment to the flattening of the real wage Phillips curve associated with labour market deregulation during the Great Moderation period. As Setterfield (2005; 2021) claim, neoliberal institutional changes have created an environment in which perpetual worker insecurity has replaced unemployment as the key labour market discipline device. Thus, in the neoliberal institutional structure, labour market disciplines workers at any rate of unemployment and prevents the profit squeeze in economic upturns. Here, I find that empirical evidence confirms the disappearance of the profit squeeze in the Great Moderation, and I draw a further implication for the properties of the business cycle. If labour productivity responds to real wages, but the latter fail to rise in the face of a tighter labour market, then labour productivity comoves less positively with output and employment over the business cycle.

The induced innovation argument implies that labour market deregulation in fact plays a role in

[5] It is perhaps not by chance that Galí and van Rens (2021) use the injury incidence rate, instead of the more commonly used hours per worker, as a proxy for labour effort to support the labour market argument. That the US economy did not exhibit a clear changing pattern in the relative volatility of employment to hours per worker is indeed implicit in Galí and van Rens (2021, Table 2).

explaining the changing pattern of labour productivity cyclicality in the US, but in a way different from the one described by New Keynesian authors. In the New Keynesian story, the decline in the cyclical correlation of labour productivity only reflects procyclical measurement errors related to variable factor utilization. If labour input could be correctly measured along both margins of adjustment, there would have been no change in the cyclical behaviour of productivity. By contrast, the labour market argument along induced innovation lines implies that the changing cyclicality of productivity reflects changes in the true state of technology of the economy over the business cycle. Thus, the breakdown of the profit squeeze associated with labour market deregulation has both short-run effects on the cyclicality of wages and productivity and long-run effects on economic growth. This paper adds to the literature on induced technical change and the real Phillips curve by addressing the impact on the cyclical behaviour of labour productivity.

3. STYLIZED FACTS

This section documents some stylized facts about output, labour productivity, real wages, and the employment rate for the US economy. The main fact that motivates this empirical investigation is the change in the cyclical behaviour of output and labour productivity in the transition from the post-war period to the Great Moderation. To the best of my knowledge, this is the first paper to provide an explanation for this change in light of the classical approach to induced innovation theory.

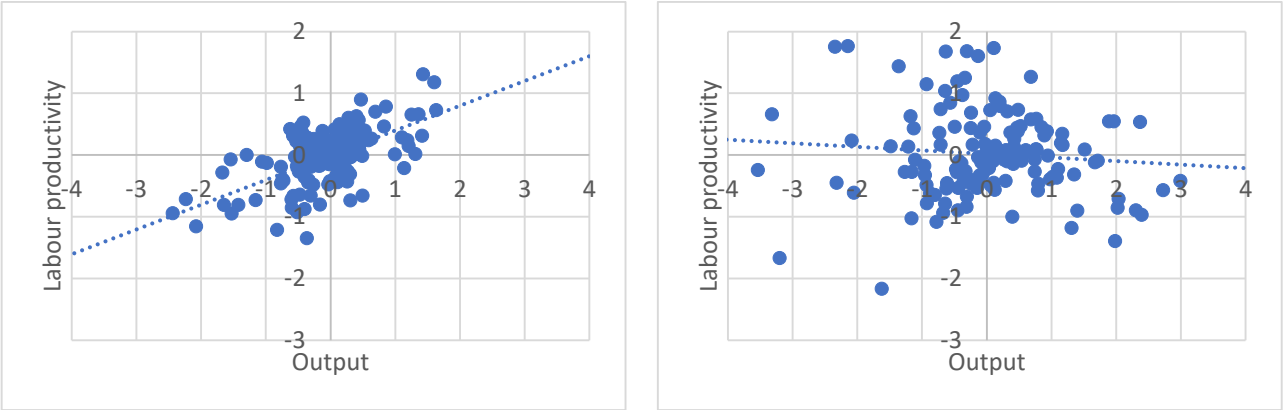
We use quarterly data for the US business and nonfarm business sectors over the period 1948Q1-2019Q4. We split the sample period into two subperiods, pre-1984 (1948Q1-1984Q4) and post-1984 (1985Q1-2019Q4), roughly corresponding to the post-war period and the Great Moderation. The break date we chose is in line with other empirical studies close in spirit to the present work, like Barnichon (2010), Mendieta-Muñoz, *et al.* (2020), and Galí and van Rens (2021). The employment rate is the complement of the civilian unemployment rate. Output, real wages, and labour productivity are computed as indices for the business and the nonfarm business sectors. The cyclical components of output, labour productivity, real wages, and employment rate in Figures 1-4 are obtained by applying the Hodrick-Prescott filter to the original series. Section 5.1 reports data description and data source of all variables of the baseline and robustness check SVAR models. Appendix A discusses further details. In this section, we limit ourselves to report the statistics of the main variables to introduce the central argument of the paper.

Figure 1 provides a graphical inspection of the change in the association between the cyclical components of output and labour productivity for the business sector in the transition from the post-war period to the Great Moderation. Figure 1a shows the scatter plot and the trend line of the relationship between output and labour productivity in the post-war period. Figure 1b displays the relationship between the two variables in the Great Moderation.[6]

As the two figures make clear, the positive association between the detrended components of output and labour productivity in the post-war period has turned into a slightly negative one in the Great Moderation. This is the first piece of evidence pointing to a change in the cyclical behaviour of output and productivity: since the mid-1980s, the pattern of the cyclicality of labour productivity has shifted from strongly procyclical to weakly countercyclical or acyclical relative to output.

[6] For a more conventional representation of the cyclicality of the four variables in terms of time series plots, see Figure B1 in Appendix B.

Fig. 1. *Changes in the cyclical association between output and labour productivity*



a) Pre-1984 *b) Post-1984*

Notes: *The series refer to the US business sector. Data are detrended using the HP filter with smoothing parameter λ=1600.*

Tab. 1. *Changes in relative volatility of labour productivity*

	Pre-1984	Post-1984
Raw series		
Business	1.090319	0.764879
Nonfarm business	1.010923	0.753470
HP filter		
Business	0.651620	0.622908
Nonfarm business	0.683534	0.602650

Note: *The relative volatility of labour productivity is computed as the ratio of the standard deviation of labour productivity to the standard deviation of output.*

The change in the cyclical association between output and labour productivity has been accompanied by a change in the volatility of labour productivity relative to the volatility of output. Table 1 summarises the evidence on relative volatility for the business and the nonfarm business sectors. Independently of whether we consider the original series or its detrended component, the relative volatility, measured as the ratio of the standard deviation of labour productivity to the standard deviation of output, has declined, consistently with our central hypothesis.

Table 2 provides evidence on changes in the volatility of two measures of labour input: employment rate and total hours worked. It displays absolute and relative standard deviations in the two subperiods for both the original and the HP-filtered series. The relative standard deviation is computed as the ratio of the standard deviation of hours to the standard deviation of employment. Table B1 in Appendix B displays absolute and relative standard deviations of hours worked and employment levels for the business and the nonfarm business sectors.

Tab. 2. *Changes in volatility of employment rate and hours worked*

	Absolute SD		SD relative to employment	
	Pre-1984	Post-1984	Pre-1984	Post-1984
Raw series				
Employment	1.752736	1.511437	–	–
Hours				
Business	7.579660	8.347409	4.324473	5.522829
Nonfarm business	9.346647	8.671981	5.332603	5.737574
HP filter				
Employment	0.934033	0.659006	–	–
Hours				
Business	1.264283	1.602440	1.353574	2.431602
Nonfarm business	1.252784	1.617608	1.341263	2.454618

The changes in absolute and relative standard deviations do not appear to support the labour market argument along New Keynesian lines. In the transition from the post-war period to Great Moderation, the US economy has faced a decline in the volatility of employment and – with the only exception of the raw series of hours in the nonfarm business sector – an increase in the volatility of hours. Independently of whether we consider the original or the transformed series, the relative volatility of total hours worked increased, suggesting growing importance of the intensive margin of adjustment (i.e. hours per worker) relative to the extensive one – a result in contrast with the basic New Keynesian argument.[7] By contrast, this piece of evidence does not affect the labour market argument along induced innovation lines.[8]

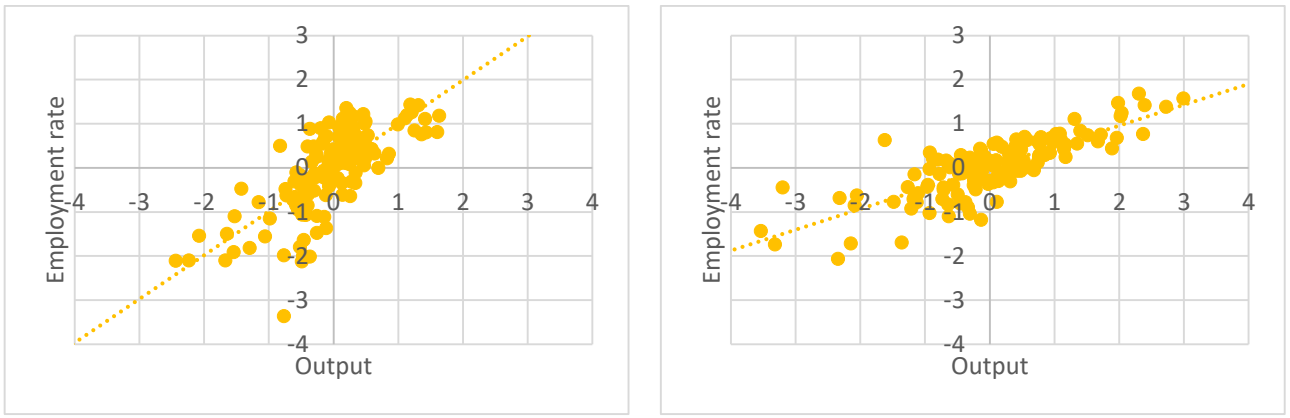
Figures 2-4 provide further evidence on the changes in the cyclical association among output, employment rate, real wages, and labour productivity for the business sector. As above, the left-hand figure shows the scatter plot and the trend line for the post-war period, the right-hand figure displays the corresponding scatter plot and trend line for the Great Moderation.

As the figures make clear, only the relationship between the employment rate and real wages has shown a significant change in the transition from the post-war period to the Great Moderation. By contrast, the patterns of association between output and employment rate, on the one hand, and real wages and labour productivity, on the other hand, are qualitatively similar across the two subperiods. The employment rate comoved positively with output over the business cycle during both the post-

[7] Table B1 in Appendix B provides mixed evidence. The relative volatility of hours computed on the raw series increased – a result in contrast with the New Keynesian labour market argument. The relative volatility of hours computed on HP-filtered data indeed decreased, but the decline appears to be small, with the relative standard deviation falling between 5,3% and 5,9%.

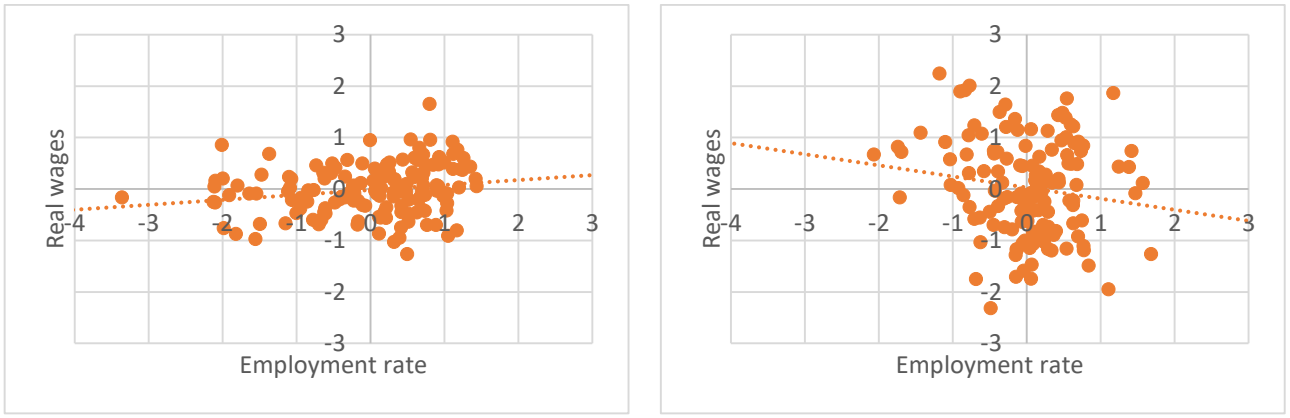
[8] Notice that this paper is silent on the factors behind the change in relative volatility of hours worked. We only want to stress that, while undermining the New Keynesian labour market argument, empirical evidence on the change in relative volatility of hours does not affect the core mechanism at play in the proposed explanation for the changing pattern of labour productivity cyclicality – induced innovation at business cycle frequencies. Moreover, Section 7 shows that the appearance of the induced innovation mechanism at business cycle frequencies is robust to the use of total hours worked as an alternative measure of labour market tightness. Thus, data support the induced innovation hypothesis – and the distributive cycle for the post-war period – irrespective of the chosen measure of labour input.

Fig. 2. *Changes in the cyclical association between output and employment rate*



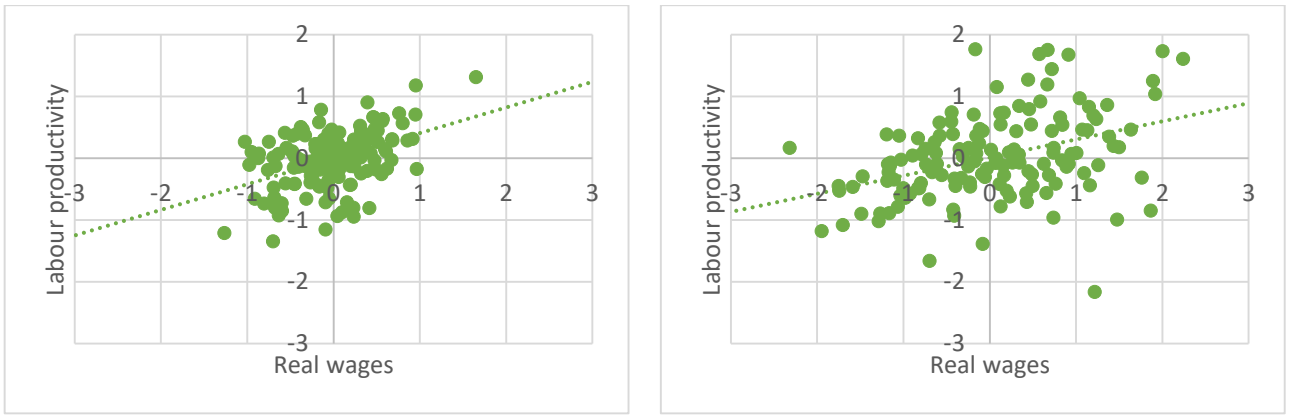
a) Pre-1984 *b) Post-1984*

Fig. 3. *Changes in the cyclical association between employment rate and real wages*



a) Pre-1984 *b) Post-1984*

Fig. 4. *Changes in the cyclical association between real wages and labour productivity*



a) Pre-1984 *b) Post-1984*

Notes: The series refer to the US business sector. Data are detrended using the HP filter with smoothing parameter λ=1600.

Tab. 3. *Changes in cyclical correlations among output, labour productivity, real wages, and employment rate*

	1948-2019	Pre-1984	Post-1984	Difference
Output and productivity				
Business	0.120604*	0.615566**	– 0.092602	– 0.708168**
Nonfarm business	0.144350*	0.644912**	– 0.102988	– 0.747900**
Output and employment				
Business	0.712182**	0.741029**	0.802749**	0.061720
Nonfarm business	0.718102**	0.740736**	0.807953**	0.067217
Employment and wages				
Business	– 0.003086	0.187372*	– 0.151279	– 0.338651**
Nonfarm business	– 0.014367	0.175681*	– 0.163206	– 0.338887**
Wages and productivity				
Business	0.403732**	0.437409**	0.394353**	– 0.043056
Nonfarm business	0.404737**	0.426605**	0.403346**	– 0.023259
Output and productivity (conditional on wages and employment)				
Business	0.342031**	0.696719**	0.802985**	0.106266*
Nonfarm business	0.360612**	0.736757**	0.789162**	0.052405

Note: * = *significant at the 5% level,* ** = *significant at the 1% level.*

war period and the Great Moderation, with only a modest decline in the slope of the trend line during the latter period (Figure 2). The slope of the trend line of employment rate and real wages has shifted from positive to negative since the mid-1980. Prior to 1985, real wages were weakly positively associated with the employment rate. Since 1985, however, the employment rate has become weakly negatively related to wages (Figure 3). The relationship between real wages and labour productivity is instead similar across the two subperiods, with labour productivity being strongly positively related to real wages at business cycle frequencies during both the post-war period and the Great Moderation (Figure 4).

Table 3 summarises the evidence on the changes in cyclical correlations among output, labour productivity, real wages, and the employment rate for the business and the nonfarm business sectors. For each pair of variables considered in Figures 1-4, Table 3 reports the computed correlation coefficients in the post-war period and the Great Moderation, as well as the subperiod difference. As above, data are detrended using the HP filter.

The first panel documents the strong decline in the cyclical correlation between output and labour productivity. Since the mid-1980s, both the business and the nonfarm business sectors have experienced a sign switch in the correlation between output and labour productivity over the cycle. Labour productivity has shifted from strongly procyclical in the post-war period to broadly acyclical in the Great Moderation. The subperiod difference is large and statistically significant at the 1% level in both sectors.

The second, third, and fourth panels show the changes in the correlation coefficients between output and employment rate, employment rate and real wages, and real wages and labour productivity,

respectively. In both sectors, labour productivity is strongly positively correlated with real wages over the business cycle, with a correlation coefficient ranging from 0.40 in the post-war period to 0.43 in the Great Moderation. The subperiod difference is small and not statistically significant. The employment rate rises with output in both subperiods, and the difference is still small and not statistically significant. By contrast, both the business and the nonfarm business sectors exhibit a significant change in the cyclical correlation between the employment rate and real wages. The correlation coefficient ranged from 0.17 and 0.19 in the pre-1984 period, and became negative but not significant in the post-1984 period. The subperiod difference is large and statistically significant at the 1% level.

The last panel displays the cyclical correlation between output and labour productivity conditional on the employment rate and real wages. It shows that, after controlling for employment and wages, in the nonfarm business sector the correlation between output and productivity does not statistically differ across the two subperiods; in the business sector the difference, albeit still significant, is remarkably smaller.

Summarising, US labour productivity has become essentially uncorrelated with output at the business cycle level. The strong procyclicality of productivity of the postwar period has completely vanished. The volatility of labour productivity has also declined relative to the volatility of output. At the same time, real wages no longer rise with the employment rate. The positive correlation between the two variables in the postwar period has switched into a negative but not significant one in the Great Moderation. By contrast, the US economy has not experienced significant changes in the output-employment and wage-productivity correlations. Conditional on the employment rate and real wages, the change in the cyclical correlation between output and labour productivity turns out to be small or not significant.

Overall, we interpret these changes as prima facie evidence in favour of an induced innovation narrative on the changing pattern of labour productivity cyclicality. Our central argument posits that part of the positive cyclical comovements between output and labour productivity is induced by the profit squeeze in distribution that the economy faces in the upturn of the business cycle. This implies that the causality goes from output to labour productivity via employment and real wages. An increase in economic activity, by raising employment and wages, stimulates labour-saving innovations, thus making labour productivity more procyclical. If real wages fail to rise in response to an increase in economic activity, labour productivity comoves less positively with output at business cycle frequencies. A breakdown of the cyclical profit squeeze may then explain part of the vanished procyclicality of labour productivity in the Great Moderation. The next sections show that the results of our SVAR analysis qualitatively conform to this story.

4. HYPOTHESES

This section discloses the empirical hypotheses that motivate our analysis. All hypotheses reflect the purpose of (i) assessing the existence and the source of the Goodwin pattern, when the labour share is decomposed into real wages and labour productivity, (ii) testing the operation of induced innovation at business cycle frequencies, and (iii) evaluating if the effects of the structural innovations on output, employment, and real wages qualitatively conform to an induced innovation account of the diminished procyclicality of labour productivity. All hypotheses are phrased in terms of signs of the impulse responses to the structural shocks to output, employment, real wages, and labour productivity – the four variables included in our non-recursively identified SVAR model. Hypotheses 1-4 follow directly from a Goodwinian framework with induced innovation. Hypothesis 5 lists the sufficient conditions for the signs of the impulse responses to account for an induced innovation

narrative on the vanishing procyclicality of labour productivity.

Denoting output by Y, the employment rate by e, and the labour share by $\omega = w/a$, where w is the real wage rate and a is labour productivity, we define our hypotheses as follows.

H1 – The economy exhibits a profit-led regime in both the (e, ω) and the (Y, ω) planes at business cycle frequencies, that is, an increase in the labour share lowers demand and employment in the short run.

H2 – The economy exhibits a profit-squeeze distribution regime in both the (e, ω) and the (Y, ω) planes at business cycle frequencies, that is, an increase in demand or employment raises the labour share in the short run.

Hypotheses 1 and 2 pertain to the *existence* of the Goodwin pattern, regardless of its source. The original Goodwin model and its subsequent developments predict counterclockwise cycles in the employment-labour share and the utilization-labour share planes, as a result of the combination of profit-led activity and profit-squeeze distribution. Economic activity leads the labour share, and the resulting profit squeeze generates a negative feedback on economic activity, giving rise to a cycle in the phase space. In a 3-D SVAR in output, employment, and labour share, this would imply a positive response of the labour share to shocks to output and employment and a negative response of employment and output to shocks to the labour share:

$$e \uparrow \Rightarrow \omega \uparrow \Rightarrow e \downarrow \tag{1}$$

$$Y \uparrow \Rightarrow \omega \uparrow \Rightarrow Y \downarrow \tag{2}$$

The standard story focuses on the Marxian mechanism of fluctuations of the reserve army of labour, resulting from the interaction of profit-constrained capital accumulation and rising wages in the face of a tightening labour market. Conditions for the recovery of profitability are restored via the labour market, as the slowdown in capital accumulation in the downturn of the business cycle replenishes the reserve army and puts downward pressure on wages. This story makes a precise statement about the *source* of the Goodwin pattern:

$$e \uparrow \Rightarrow w \uparrow \Rightarrow e \downarrow \tag{3}$$

$$Y \uparrow \Rightarrow w \uparrow \Rightarrow Y \downarrow \tag{4}$$

However, in the context of 4-D SVAR with a decomposed labour share, an increase in the labour share may be caused either by an increase in real wages or by a decrease in labour productivity. Thus, the Goodwin pattern may arise in principle either from the interaction between real wages and the employment rate (expressions (3) and (4)) or from the interaction between the employment rate and labour productivity:

$$e \uparrow \Rightarrow a \downarrow \Rightarrow e \downarrow \tag{5}$$

$$Y \uparrow \Rightarrow a \downarrow \Rightarrow Y \downarrow \tag{6}$$

or some combinations such that the overall effect is the one expressed by (1) and (2).

In this paper, we take a neutral theoretical stance on the overall causes of the Goodwin pattern. Hypotheses 1 and 2 concerns the *existence* of the Goodwin pattern, aiming to test (1) and (2) in the context of a decomposed labour share. Thus, for our purposes here, we limit ourselves to assess whether the economy exhibits profit-led activity and a profit squeeze in distribution at business cycle frequencies. A demand and employment regime is profit-led if a distributive or technology shock raising the labour share has a negative effect on output and employment, and a distributive regime is

profit-squeeze if a positive shock to output and employment raises real wages and/or reduces labour productivity.[9]

H3 – A positive structural shock to the employment rate raises real wages.

Hypothesis 3 pertains to the *source* of the profit-squeeze distribution regime in the (ω, e) space. It states that at least part of the decline in the profit share in the upturn of the business cycle stems from real wage increases:

$$e \uparrow \Rightarrow w \uparrow \tag{7}$$

This hypothesis is in accordance with the conventional account of the source of the Goodwin pattern and with a real wage Phillips curve in mainstream economics.

H4 – A positive structural shock to the real wage raises labour productivity.

Hypothesis 4 is our empirical test for the induced innovation theory along classical-Marxian lines, that posits that an increase in labour costs acts as an incentive for firms to adopt labour-saving innovations. It is phrased in terms of response of labour productivity to real wages.

$$w \uparrow \Rightarrow a \uparrow \tag{8}$$

In the classical-Marxian view, labour-saving technical change is a weapon of the capitalist class in the distributive conflict, as it allows capitalists to counteract profit squeezing with increases in labour productivity.

H5 – If the following conditions are satisfied: (i) H4 holds in both the pre-1984 and the post-1984 periods, (ii) a demand shock raises employment in both the pre-1984 and the post-1984 periods, and (iii) H3 holds only in the pre-1984 period; then a failure of wages to sufficiently respond to employment accounts for part of the vanished procyclicality of labour productivity in the Great Moderation.

Hypothesis 5 summarises our induced innovation narrative on the changing pattern of cyclicality of US labour productivity. It posits that the real wage Phillips curve and induced technical change are an additional source of procyclicality in labour productivity. If the response of real wages to the employment rate is strong enough over the business cycle, and labour-saving innovations are driven by real wage increases, then labour productivity comoves more positively with output at business cycle frequencies:

$$Y \uparrow \Rightarrow e \uparrow \Rightarrow w \uparrow \Rightarrow a \uparrow \tag{9}$$

This hypothesis implies that, if distribution-induced technical change is a significant driver of labour productivity over the cycle, a vanishing real wage Phillips curve during the Great Moderation explains part of the reduced cyclicality of labour productivity. Thus, while in the post-war period an increase in economic activity led to an increase in labour productivity via employment and wages, as described by expression (9), in the Great Moderation labour productivity did not respond any longer to changes in economic activity via real Phillips curve:

$$Y \uparrow \Rightarrow e \uparrow \not\Rightarrow w \uparrow \Rightarrow a \uparrow \tag{10}$$

[9] Of course, impulse response functions of our SVAR analysis give an additional piece of information on the source of the Goodwin pattern, but a theoretical investigation of the driving forces of the distributive cycle is not the main purpose of this paper. Thus, our findings in Sections 6-7 open theoretical questions for further research.

5. DATA AND EMPIRICAL METHODOLOGY

5.1. DATA

In the baseline model, we employ quarterly data for the US business sector coming from the Federal Reserve Bank of St. Louis Economic Database (FRED) and covering the period 1948Q1-2019Q4. We left out the post-2019 period due to the short time series available after the Covid-19 pandemic crisis. The employment rate is the reminder to 100 of the civilian unemployment rate. Time series of output, real wages, and labour productivity refer to the business sector. Real wages correspond to real hourly compensation. Labour productivity is defined as real output per hour. All variables except the employment rate are indexed as 2012 = 100. Appendix A reports further details on data description and data source of the variables used across all model specifications.

We chose 1984Q4 as a structural break date, in accordance with other empirical studies on the determinants of US income distribution in the spirit of neo-Goodwinian theory (Mendieta-Muñoz, *et al.*, 2020) or on the changes in the cyclical behaviour of US labour productivity (Barnichon, 2010; Galí and van Rens, 2021). Thus, we split the overall period into two subperiods: the post-war period (1948Q1-1984Q4) and the Great Moderation (1985Q1-2019Q4).

In the baseline and all robustness check models, data are detrended applying the Hodrick-Prescott filter, with smoothing parameter $\lambda = 1600$.

5.2. METHODOLOGY AND IDENTIFICATION STRATEGY

This paper uses a vector autoregressive (VAR) methodology to test the five hypotheses that motivate our analysis. Popularized by Sims (1980), VAR models have been widely used for multivariate time series analysis for their "atheoretical" structure, as they limit themselves to express each model variable in terms of its own lags and lags of the other model variables. However, a standard reduced-form VAR model cannot be given a causal interpretation, as it rules out contemporaneous correlations and its residuals are typically mutually correlated. Recovering the (mutually uncorrelated) structural shocks from the reduced-form representation of a VAR model requires imposing identifying restrictions on the data-generating process, motivated on the basis of economic theory.

In contrast to the more popular recursively identified models, our identification strategy orthogonalizes the reduced-form errors by imposing restrictions that do not constrain the matrix of contemporaneous effects to have a lower (or upper) triangular structure.[10] A non-recursive strategy is particularly appealing for high-dimensional VAR models in the spirit of classical-Keynesian theory, as it allows income distribution and economic activity to have contemporaneous effects on each other. In low-dimensional models including only one variable for economic activity (either output/utilization or employment) and one distributive variable, structural innovations can be properly identified by means of a recursive strategy, as the "standard ordering" of variables can be easily motivated on a theoretical ground.[11] However, in the context of higher-dimensional VAR models, possibly including both demand and employment, a classical-Keynesian account of the business cycle cannot be immediately translated into a particular causal chain among variables. A non-recursive strategy is instead well-suited to identify structural innovations, allowing economic activity to feed back into income distribution via the labour market. Thus, differently from a recursive

[10] For a similar non-recursive identification strategy in empirical studies on the distributive cycle, see Santetti (n.d.) and Mendieta-Muñoz, *et al.* (2021).

[11] See Section 2.

identification strategy, it can simultaneously allow for distribution-led demand, a demand-driven labour market, and income distribution determined by the state of the labour market, which constitute the basic "ingredients" of a classical-Keynesian theory of the business cycle.

Our four-dimensional dynamic system includes output (Y_t), employment (e_t), real wages (w_t), and labour productivity (a_t) and can be represented as a structural vector autoregressive (SVAR) model as follows:

$$\boldsymbol{A x_t} = \boldsymbol{\alpha} + \sum_{i=1}^{p} \boldsymbol{A_i x_{t-i}} + \boldsymbol{B \varepsilon_t} \tag{11}$$

where $\boldsymbol{x_t} = (Y_t, e_t, w_t, a_t)$ is a vector of endogenous variables, $\boldsymbol{\alpha}$ is a 4×1 vector of intercepts, $\boldsymbol{A}$ is a 4×4 matrix of contemporaneous effects among the endogenous variables, $\boldsymbol{A_i}$, with $i = 1, \dots, p$, are 4×4 matrices of structural slope coefficients, $\boldsymbol{B}$ is a 4×4 matrix of the correlation structure of the structural innovations, and $\boldsymbol{\varepsilon_t}$ is a 4×1 vector of mean zero and serially uncorrelated structural innovations.

Only the structural shocks may be given a causal interpretation and are suitable to build economically meaningful impulse response functions, but in general they are not directly observable. However, postulating that matrix $\boldsymbol{A}$ is invertible, the structural shocks may be recovered from the reduced-form representation of the model.

The corresponding reduced-form VAR model can be represented as follows:

$$\boldsymbol{x_t} = \boldsymbol{\gamma} + \sum_{i=1}^{p} \boldsymbol{C_i x_{t-i}} + \boldsymbol{u_t} \tag{12}$$

where $\boldsymbol{\gamma}$ is a 4×1 vector of reduced-form intercepts, $\boldsymbol{C_i}$, with $i = 1, \dots, p$, are 4×4 matrices of reduced-form slope coefficients, and $\boldsymbol{u_t} = \boldsymbol{A^{-1} B \varepsilon_t}$ is a 4×1 vector of mutually correlated reduced-form residuals.

Identification of the SVAR model (11) requires imposing some credible restrictions on the matrix $\boldsymbol{A}$ of the contemporaneous effects among variables and/or on the matrix $\boldsymbol{B}$ of the correlation structure of the structural shocks. In this paper, we only impose zero restrictions on the off-diagonal entries of $\boldsymbol{A}$, motivated on the basis of economic theory, while setting the diagonal elements of $\boldsymbol{A}$ to unity and leaving $\boldsymbol{B}$ as a diagonal matrix. Thus, since we have $n = 4$ variables, the order condition for a just-identified SVAR model requires the off-diagonal entries of $\boldsymbol{A}$ to have $n(n-1)/2 = 6$ restrictions.

We can illustrate the link between reduced-form residuals and structural innovations in terms of an AB-type model:[12]

$$\boldsymbol{A u_t} = \boldsymbol{B \varepsilon_t} \tag{13}$$

$$\begin{bmatrix} 1 & a_{12} & a_{13} & a_{14} \\ a_{21} & 1 & a_{23} & a_{24} \\ a_{31} & a_{32} & 1 & a_{34} \\ a_{41} & a_{42} & a_{43} & 1 \end{bmatrix} \begin{bmatrix} u_t^Y \\ u_t^e \\ u_t^w \\ u_t^a \end{bmatrix} = \begin{bmatrix} b_{11} & 0 & 0 & 0 \\ 0 & b_{22} & 0 & 0 \\ 0 & 0 & b_{33} & 0 \\ 0 & 0 & 0 & b_{44} \end{bmatrix} \begin{bmatrix} \varepsilon_{1t} \\ \varepsilon_{2t} \\ \varepsilon_{3t} \\ \varepsilon_{4t} \end{bmatrix} \tag{14}$$

[12] See Lütkepohl (2005, Section 9.1).

Guided by classical-Keynesian growth theory, we do the following assumptions on the entries of matrix $\boldsymbol{A}$:

(i) $a_{12} = 0$, a_{13} and a_{14} unrestricted;
(ii) $a_{23} = 0$, a_{21} and a_{14} unrestricted;
(iii) $a_{31} = 0$, $a_{34} = 0$, a_{32} unrestricted;
(iv) $a_{41} = 0$, $a_{42} = 0$, a_{43} unrestricted.

Assumption (i) states that output is left free to respond contemporaneously to real wages and labour productivity, but is constrained to react only with a lag to employment. This assumption reflects standard post-Keynesian growth theory, in which the labour share affects economic activity and growth via both the Keynesian accelerator and cost-side profitability (Bhaduri and Marglin, 1990; Marglin and Bhaduri, 1990). In the context of a decomposed labour share, this implies contemporaneous links from both real wages and labour productivity to output. A positive sign for the estimated a_{13} implies that real wages have a negative contemporaneous impact on economic activity, in line with the conventional account of the source of a profit-led demand regime.[13]

Assumption (ii) allows employment to react to output and labour productivity, but not to real wages, within the same quarter. This assumption reflects the standard Keynesian view that employment is primarily driven by the level of economic activity and also allows productivity to feed back into employment. Together, assumptions (i) and (ii) imply that the labour market is contemporaneously affected by the state of the goods market, but the latter responds to the former only with a lag – which is again in line with a demand-side perspective on the drivers of the business cycle.

Assumption (iii) states that real wages contemporaneously react to employment, but have a lagged response to output and labour productivity. This assumption is in accordance with a real wage Phillips curve in mainstream economics and with the standard Goodwinian story of profit squeezing as a result of a tighter labour market. Thus, we expect the estimated a_{32} to have a negative sign.

Assumption (iv) implies that labour productivity is contemporaneously affected by real wages, but not by output and employment. This assumption summarizes the induced innovation hypothesis: rising real wages provide the incentive for capitalists to invest in labour-saving innovations, thus raising labour productivity.

Using assumptions (i)-(iv), our AB-type model can be represented as follows:

$$\begin{bmatrix} 1 & 0 & a_{13} & a_{14} \\ a_{21} & 1 & 0 & a_{24} \\ 0 & a_{32} & 1 & 0 \\ 0 & 0 & a_{43} & 1 \end{bmatrix} \begin{bmatrix} u_t^Y \\ u_t^e \\ u_t^w \\ u_t^a \end{bmatrix} = \begin{bmatrix} b_{11} & 0 & 0 & 0 \\ 0 & b_{22} & 0 & 0 \\ 0 & 0 & b_{33} & 0 \\ 0 & 0 & 0 & b_{44} \end{bmatrix} \begin{bmatrix} \varepsilon_{1t} \\ \varepsilon_{2t} \\ \varepsilon_{3t} \\ \varepsilon_{4t} \end{bmatrix} \tag{15}$$

Equation (15) summarizes our identifying restrictions for getting a just-identified SVAR model of the kind of (11). These restrictions are guided by classical-Keynesian economic theory and allow us to properly identify the mean zero and serially uncorrelated structural innovations we need to compute impulse response functions. Thus, we can assess the impact of structural innovations on the endogenous variables of the system.

[13] Remind that, in the matrix notation of (13) and (14), all the reduced-form residuals appear on the left-hand side. Thus, the signs of contemporaneous effects are reversed.

6. RESULTS

In this section, we report and discuss the results based on impulse response functions (IRFs) and forecast error variance decomposition (FEVD) estimated for our baseline model. Our preferred specification is a SVAR model identified according to equation (15) and includes the employment rate, and output, real wages, and labour productivity of the business sector. All variables are transformed by means of a filtering technique (the HP filter), as the focus of this paper is on dynamic interactions at business cycle frequencies. The next section shows that the results of our baseline model are robust to the use of different measures of economic activity and labour market tightness and a different identification strategy allowing for a contemporaneous effect of demand on productivity.

We first estimated IRFs and FEVD for the whole period. Our findings confirm the induced innovation hypothesis, as real wages have a positive and persistent effect on labour productivity. Then, we estimated IRFs for both the post-war period (1948Q1-1984Q4) and the Great Moderation (1985Q1-2019Q4). Our results empirically support profit-led demand and employment regimes and the induced innovation hypothesis in both subperiods. The effect of employment on real wages turned from positive in the pre-1984 period to insignificant in the Great Moderation. In this section, we only reported the IRFs we need to empirically evaluate our five hypotheses. Complete results for the baseline and robustness check models are shown in Appendix D. IRFs are computed over a 10-quarter horizon. The black line gives the response of the variable of interest to structural innovations. The corresponding 95% confidence interval is depicted by orange lines.

We performed an Augmented Dickey-Fuller (ADF) test to exclude the presence of unit roots, finding that all detrended series are indeed stationary. The baseline model includes 2 lags, as different information criteria indicated this is the optimal lag length for our VAR model and Lagrange Multiplier (LM) tests excluded the presence of serious autocorrelation problems. All real and imaginary roots of the characteristic polynomial lie inside the unit circle, which ensures the stability of the estimated VAR model (see Appendix C).

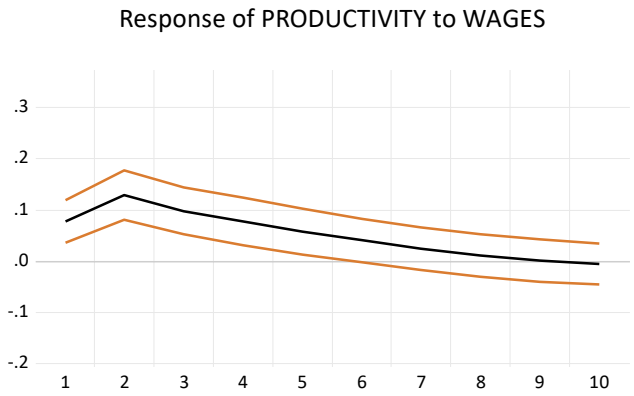
Figure 5 shows the response of labour productivity to real wages derived from the SVAR model for the whole period. A positive shock to wages has a positive and persistent effect on labour productivity, in line with the predictions of the theory of induced innovation. The effect is significant up to the fifth quarter. FEVD in Table 4 shows that, within a 1-2 year forecast horizon, wage shocks explain a consistent fraction of total variation in labour productivity (between 14% and 17,5%), suggesting that distributive shocks play an important role in determining changes in technology.

Figures 6-7 report selected IRFs for testing the profit-led and profit-squeeze pattern in the pre-1984 period. Figures 8-9 display the corresponding IRFs for the post-1984 period.

The US economy followed a profit-led and profit-squeeze pattern at the business cycle level during the post-war period, thus conforming to expressions (1) and (2). In the (e, ω) space, we found that a positive shock to employment raises real wages for one quarter and has a marginally negative effect on labour productivity in quarters 3-4, whereas a productivity shock has a strong positive effect on employment for five periods (quarters 3-7). However, we did not find evidence that distributive shocks affect the employment rate over a 10-quarter horizon. In the (Y, ω) plane, after a short-lived positive effect in quarter 2, a demand shock has a negative and persistent impact on labour productivity (quarters 5-9), whereas technology shocks strongly and positively affect output up to the 6th quarter. Again, distributive shocks appear to have no effects on economic activity. Moreover, wages do not respond to fluctuations in demand.

IRFs in Figures 6-7 support the existence of a distributive cycle in both the (e, ω) and the (Y, ω) spaces in the US post-war period, in line with our Hypotheses 1 and 2. Furthermore, the real wage Phillips curve is a driver of the profit-squeeze distribution regime in (e, ω), as shocks to employment have a positive, though not so persistent, effect on wages – a result that confirms Hypothesis 3 for the

Fig. 5. *IRF for testing H3 (whole period)*



Tab. 4. *Variance decomposition of labour productivity, 1948-2019*

Time horizon	Output	Employment	Wages	Productivity
1	0.006107	0.071037	4.778061	95.14480
2	0.208347	0.049957	12.70328	87.03842
3	0.795844	0.295040	16.02603	82.88309
4	4.540278	0.548085	17.53181	77.37983
5	11.44880	0.620525	17.38939	70.54129
6	19.19787	0.567490	16.31579	63.91885
7	25.74398	0.545140	15.04684	58.66404
8	30.34640	0.642234	13.99078	55.02059

first subperiod. However, in our baseline estimates, the observed profit-led pattern in (e, ω) and (Y, ω) appears to be largely driven by movements in labour productivity, rather than in real wages, as the impact of distributive shocks on economic activity and employment is not significant.

During the Great Moderation, the US economy still exhibited profit-led demand and employment at business cycle frequencies, but the profit-squeeze distribution regime in the (e, ω) space appears to have vanished. Neither wages nor productivity significantly respond to changes in labour market tightness over a 10-quarter horizon. As above, positive technology shocks have a positive and persistent effect on employment (quarters 3-6). Moreover, a positive shock to wages now lowers the employment rate for one quarter. In the (Y, ω) plane, demand shocks significantly reduce labour productivity for eight periods (quarters 3-10), whereas productivity shocks have a positive effect on output for the first five quarters. As in the first subperiod, output does not react to shocks to real wages, and the latter does not respond to demand shocks.

IRFs in Figures 8-9 are consistent with a distributive cycle in the (Y, ω) space, but not in (e, ω), where profit squeeze in distribution completely vanished. Thus, empirical evidence for the Great Moderation supports both Hypotheses 1 and 2 in (Y, ω), but only Hypothesis 1 in (e, ω). Moreover, differently from the post-war period, distributive shocks have a negative effect on employment, in line with the Marxian account of profit-constrained capital accumulation. Thus, an increase in the labour share, irrespective of whether is caused by a positive wage shock or by an adverse technology shock, always slows down employment at business cycle frequencies. In addition, real wages no longer rise with employment, that is, the real wage Phillips curve has become flat, in contrast with

Fig. 6. *IRFs for testing H1 (post-war period)*

Fig. 7. *IRFs for testing H2-H3 (post-war period)*

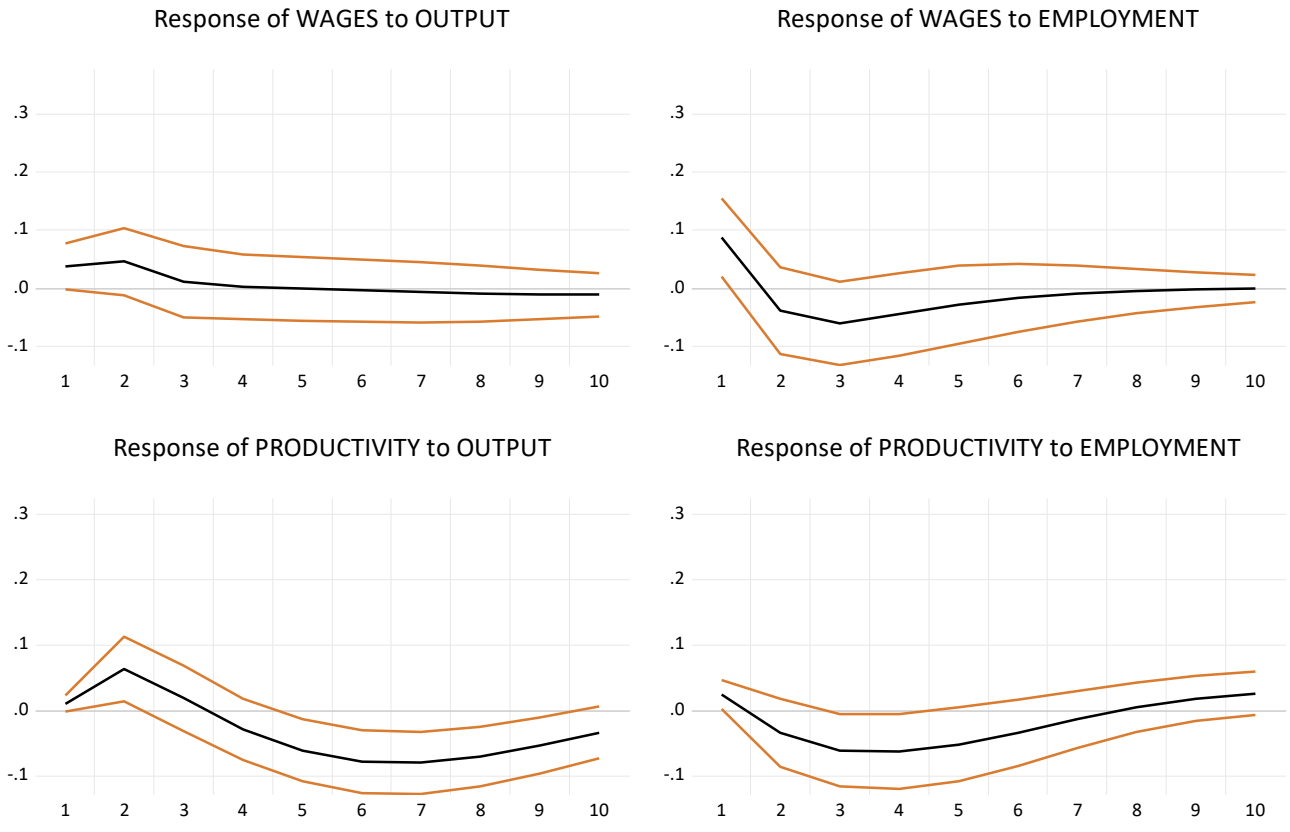


Fig. 8. *IRFs for testing H1 (Great Moderation)*

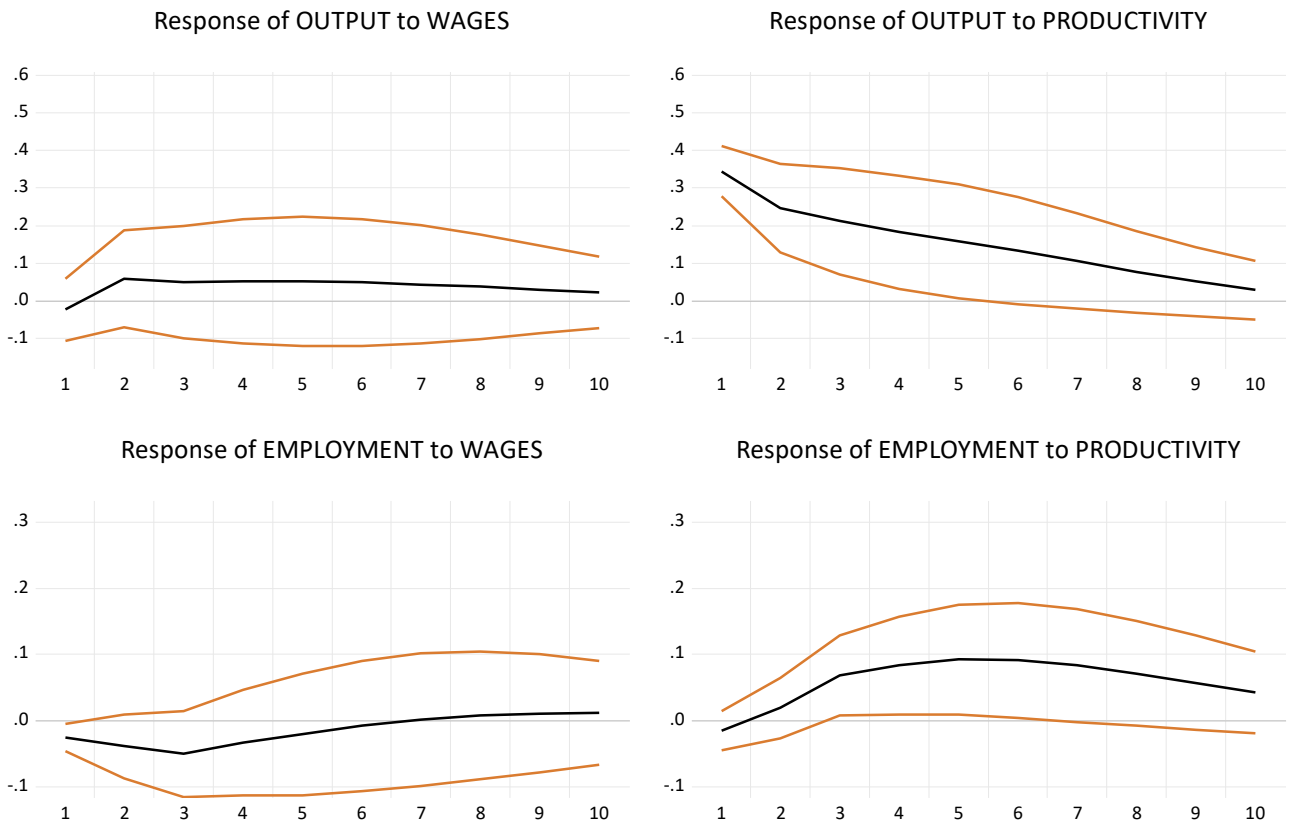


Fig. 9. *IRFs for testing H2-H3 (Great Moderation)*

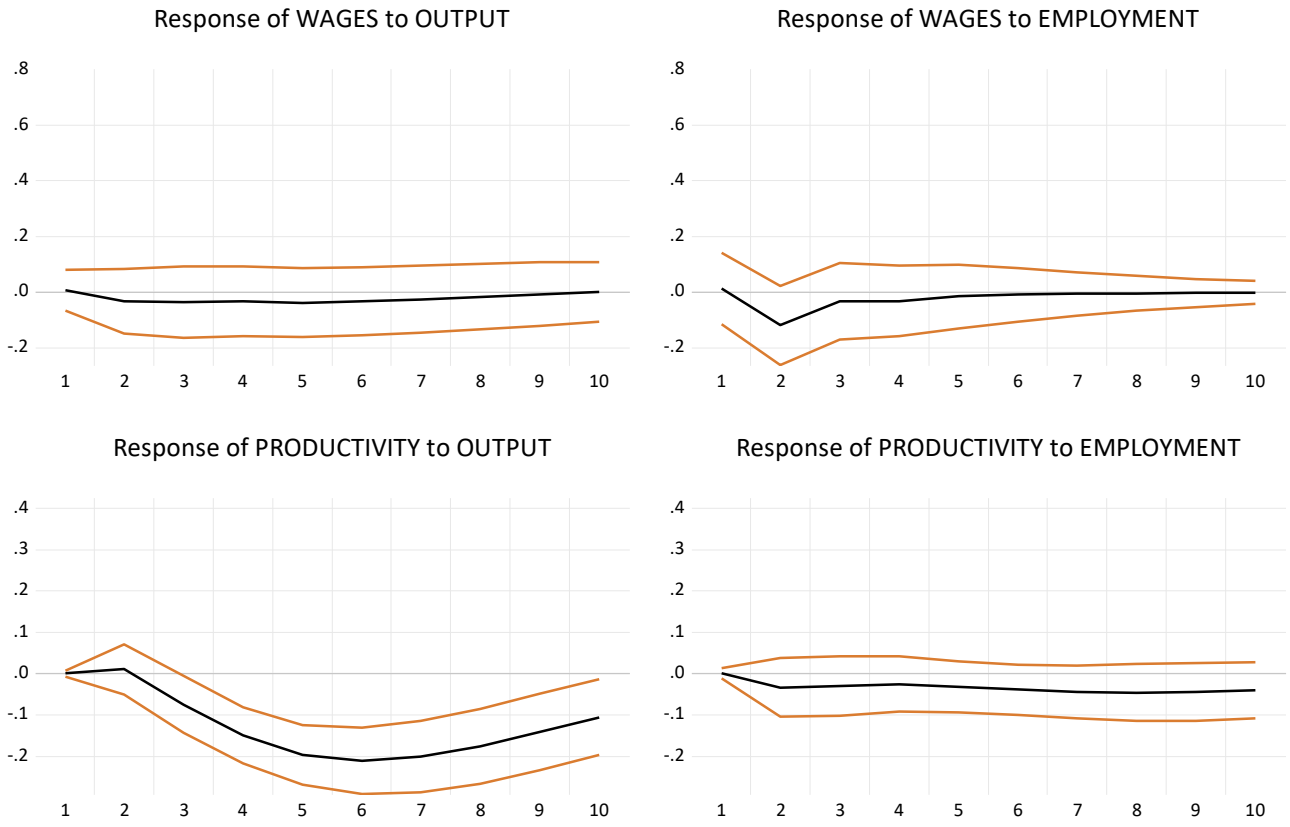
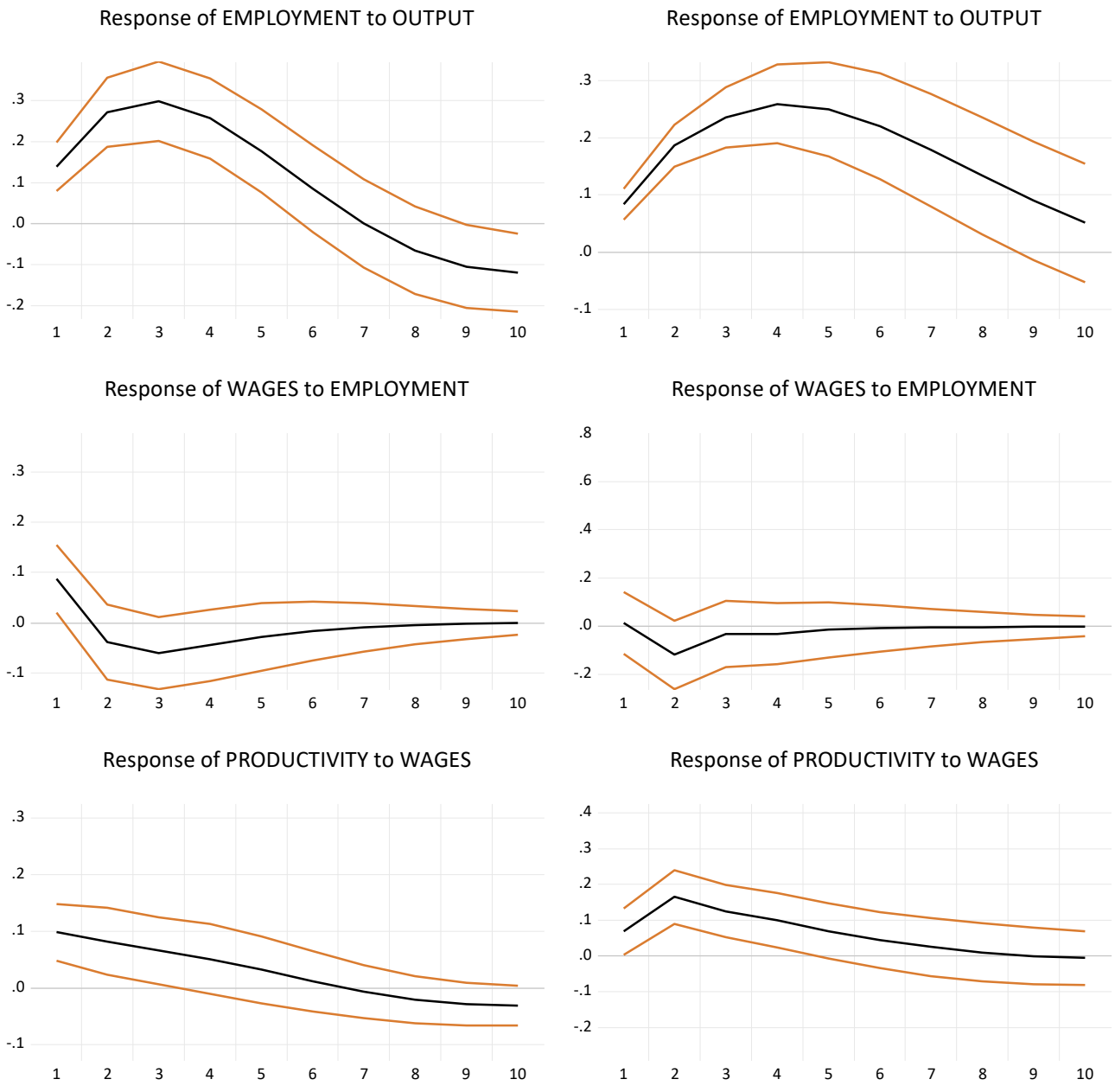


Fig. 10. *IRFs for testing H4-H5 (post-war period and Great Moderation)*



a) Pre-1984 *b) Post-1984*

our Hypothesis 3. Labour productivity still decreases in response to demand shocks, a fact that explains the survival of profit-squeeze distribution in (Y, ω). This result could be due to the presence of reallocation effects in recessions, that is, reallocation of resources from low productive firms or sectors towards more productive ones following adverse demand shocks. Notice that this result needs not imply a rejection of the Kaldor-Verdoorn effect, which typically operates at higher frequencies than the ones captured by applying filtering techniques.[14]

[14] For a SVAR analysis on the long-run effects of the growth rate of output on labour productivity, which empirically supports a technical progress function *à la* Kaldor-Verdoorn, see Antenucci, *et al.* (2020).

Tab. 5. *Estimated coefficients of matrices* ***A*** *and* ***B***

	Pre-1984		Post-1984	
	Coefficients	Prob.	Coefficients	Prob.
a_{13}	0.245257	0.0000	0.118021	0.0062
a_{14}	– 0.832982	0.0000	– 0.903600	0.0000
a_{21}	– 0.794165	0.0000	– 0.271560	0.0000
a_{24}	0.467261	0.0093	0.285146	0.0000
a_{32}	– 0.267887	0.0129	– 0.090623	0.8328
a_{43}	– 0.292383	0.0000	– 0.094706	0.0358
b_{11}	0.181057	0.0000	0.310678	0.0000
b_{22}	0.337397	0.0000	0.150088	0.0000
b_{33}	0.348290	0.0000	0.719778	0.0000
b_{44}	0.286451	0.0000	0.380614	0.0000

Figure 10 reports the IRFs for testing our induced innovation account of the diminished procyclicality of labour productivity. Figure 10a displays the IRFs for the post-war period. Figure 10b shows the corresponding IRFs for the Great Moderation. Table 5 reports the estimated coefficients of matrices ***A*** and ***B*** in the two subperiods.

The impact of structural innovations on output, employment, and real wages qualitatively conform to our narrative on the changing pattern of cyclicality of US labour productivity, in accordance with expression (9) for the post-war period and expression (10) for the Great Moderation. A wage shock significantly raises labour productivity up to the 3rd quarter in the pre-1984 period and up to the 4th quarter in the post-1984 period. A demand shock has a strong and positive effect on employment for five quarters in the first subperiod and for eight quarters in the second subperiod. The response of wages to employment has turned from positive in the post-war period to insignificant during the Great Moderation.

IRFs in Figure 10 support Hypotheses 4 and 5 on induced innovation and the cyclicality effects of the disappearance of the real wage Phillips curve. In the US post-war period, a highly regulated labour market allowed workers to have sufficient bargaining power to claim for higher wages in the expansionary phase of the business cycle. Upward wage pressures in booms forced capitalists to protect their profit margins by adopting more labour-saving innovations. Thus, labour productivity comoved more positively with output over the cycle. The transition to the Great Moderation brought about a flat real Phillips curve – real wages failed to rise in response to an increase in labour market tightness. Distribution-induced innovation was still an important driver of labour productivity, but missing wage growth in the upturn of the business cycle implies that labour productivity failed to respond to fluctuations in economic activity and employment. As a result, labour productivity comoved less positively with output at business cycle frequencies.

A comparison of the estimated coefficients of the matrix of contemporaneous effects in the two subperiods appears to support the intuition as well. The left-hand panel of Table 5 reports the estimated coefficients of matrices ***A*** and ***B*** for the post-war period. The right-hand panel displays the corresponding coefficients for the Great Moderation. As the table makes clear, in both subperiods real wages have a positive and significant contemporaneous impact on labour productivity. However, the contemporaneous effect of the employment rate on real wages has turned from positive and significant in the pre-1984 period to not significant during the Great Moderation.

Table 6 summarizes our findings. Impulse responses support both the induced innovation hypothesis and the existence of Goodwin cycles in the (e, ω) and (Y, ω) spaces for the post-war

Tab. 6. *Summary of results*

	Pre-1984	Post-1984
H1 – Profit-led pattern	Yes	Yes
H2 – Profit-squeeze pattern	Yes	Yes, in (Y, ω); no, in (e, ω)
H3 – Real Phillips curve	Yes	No
H4 – Induced innovation hypothesis	Yes	Yes
H5 – Induced innovation account of the changing cyclicality of productivity	Yes	

period, though the profit-led regime appears to be determined by technology rather than distributive shocks. During the Great Moderation, the profit-led regime in (e, ω) is determined by both technology and distributive shocks, but the profit-squeeze regime in (e, ω) is completely broken. However, income distribution is still a driver of labour-saving innovations, as structural innovations to wages raise labour productivity. Thus, part of the changes in economic activity and employment are the result of wage-led technology shocks, though the disappearance of the cyclical profit squeeze does not allow labour productivity to significantly react to fluctuations in economic activity through the induced innovation channel. We then conclude that impulse responses in the two subperiods qualitatively support an induced innovation account of the vanishing procyclicality of US labour productivity.

7. ROBUSTNESS CHECKS

This section performs some robustness analyses. We show that the main findings of our baseline model identified according to equation (15) are robust to the use of different measures of economic activity (i.e. output gap or GDP instead of output for the business sector) and different measures of labour market tightness (i.e. employment levels or hours worked instead of the employment rate). As a further robustness check, we identify structural innovations with restrictions allowing demand to have a contemporaneous impact on productivity, as in Mendieta-Muñoz, *et al.* (2021). All model specifications provide empirical support to the existence of the Goodwin pattern, the weakening of the Phillips curve effect during the Great Moderation, and the induced innovation hypothesis. Only the impact of distributive shocks on output and employment appears to be sensitive to the chosen measure of labour market tightness. However, across almost all model specifications, the effect of technology shocks on output and employment is positive and persistent. IRFs for all estimates are reported in Appendix D.

As in the baseline specification, we preliminarily tested for the presence of unit roots, the optimal lag length, serial correlation, and VAR stability. A VAR model with 2 lags passed the relevant tests in all specifications except the one with hours worked, for which information criteria and LM tests suggested the inclusion of 3 lags.

First, we report IRFs obtained by a SVAR model identified according to equation (15) and in which output of the business sector is replaced by output gap for the total economy as a measure of

economic activity (Figure D2 in Appendix D). In both subperiods, the economy exhibits profit-led demand and employment following a technology shock, as the response of output and employment to labour productivity is positive and persistent. As in the baseline model, a distributive shock in favour of the labour share hurts employment for one quarter in the post-1984 period. Wage shocks raise labor productivity for three quarters in the first subperiod and four quarters in the second one, which confirms the induced innovation hypothesis. The response of wages to an increase in labour market tightness supports our argument on the changing pattern of cyclicality along induced innovation lines, as it switched from positive in the pre-1984 period to not significant during the Great Moderation. However, positive shocks to employment appear to squeeze profits in both subperiods, through a strong and persistent negative impact on labour productivity.

Second, we estimated a model specification including the detrended component of GDP as an alternative measure of economic activity. IRFs reported in Figure D3 show that the effects of structural innovations in this specification are qualitatively similar to those found in the baseline model. In the pre-1984 period, profit-led demand and employment are entirely determined by technology shocks. After 1984, profit-led demand is still driven by technology shocks, which have a positive effect on output up to the 5th quarter, whereas profit-led employment is caused by a one-quarter negative effect of wage shocks. The cyclical profit squeeze in the (e, ω) plane appears to have vanished during the Great Moderation. This result, along with the induced innovation hypothesis, qualitatively supports our hypothesis about the changing cyclicality of productivity.

In order to test if our five hypotheses are robust to the chosen measure of labour market tightness, we estimated a model specification including data on employment levels for the business sector instead of the employment rate (Figure D4). Again, evidence supports the induced innovation hypothesis in both subperiods. A positive shock to wages raises labour productivity for three quarters in the pre-1984 period and four quarters during the Great Moderation. Furthermore, profit-squeeze distribution is observed in both the (Y, ω) and the (e, ω) spaces during the post-war period, but only in (Y, ω) during the Great Moderation. The disappearance of the real wage Phillips curve again supports the induced innovation argument on the cyclical behaviour of productivity.

For what concerns the effects of the labour share on output and employment, IRFs return a more complex picture. As before, technology shocks persistently raise output and employment in the pre-1984 period. However, the effect of wage shocks on employment switches from negative in the first two quarters to positive in quarters 8-10. An increase in wages also marginally raises output in quarters 7-8. Thus, the economy exhibits profit-led demand and employment up to quarters 6-7, but output and employment rise thereafter for about two quarters following a wage shock. This result could be supportive of the view that demand is more likely to be profit-led in the short run and more likely to be wage-led at longer time horizons (Blecker, 2016). During the Great Moderation, output and employment do not appear to respond to distributive shocks, whereas technology shocks against the labour share still raise output up to the 4th quarter.

As an additional robustness check, we estimated a model specification in which the employment rate is replaced by total hours worked, which implicitly considers both the extensive and the intensive margins of labour adjustment (Figure D5).[15] The response of output and hours worked to the labour share shows a similar pattern as before. In the pre-1984 period, technology shocks have a positive and persistent effect on output and hours, whereas wage shocks reduce hours in the first quarter but raise output and hours for three quarters after about two years. During the Great Moderation, technology shocks raise output for two quarters, but the response of output and hours to distributive shocks turns out to be insignificant. Furthermore, wage shocks raise labour productivity in both subperiods, in line with the induced innovation hypothesis. Wages positively react to increases in hours for two quarters before 1984 and for one quarter thereafter. Thus, the cyclical profit squeeze is

[15] We estimated this model using data for the US nonfarm business sector, as estimates for the business sector did not lead to reliable impulse response functions due to the high values of the standard errors of the structural coefficients.

still present, albeit weakened, in the Great Moderation period.

Finally, as VAR models motivated on the basis of neo-Goodwinian theory have been criticized by supporters of wage-led growth for their supposed failure to account for procyclical variation in labour productivity,[16] we estimated a further specification allowing demand to affect contemporaneously labour productivity. We adopted the identifying restrictions originally proposed by Mendieta-Muñoz, *et al.* (2021) in their study on the evolution of the drivers of the US labour share. This model specification is then estimated on HP-filtered data on the same variables as in our baseline model, but is identified as follows:

$$\begin{bmatrix} 1 & 0 & a_{13} & a_{14} \\ a_{21} & 1 & 0 & a_{24} \\ 0 & a_{32} & 1 & 0 \\ a_{41} & 0 & 0 & 1 \end{bmatrix} \begin{bmatrix} u_t^Y \\ u_t^e \\ u_t^w \\ u_t^a \end{bmatrix} = \begin{bmatrix} b_{11} & 0 & 0 & 0 \\ 0 & b_{22} & 0 & 0 \\ 0 & 0 & b_{33} & 0 \\ 0 & 0 & 0 & b_{44} \end{bmatrix} \begin{bmatrix} \varepsilon_{1t} \\ \varepsilon_{2t} \\ \varepsilon_{3t} \\ \varepsilon_{4t} \end{bmatrix} \tag{16}$$

Equation (16) leaves productivity free to respond to output within the same quarter but constrains labour productivity to react to wages with a lag.

Figure D6 displays the effects of structural innovations on output, employment rate, wages, and productivity in the two subperiods. As the IRFs make clear, our findings are qualitatively unchanged. Wage shocks raise productivity for three or four quarters in both subperiods. The transition to the Great Moderation is marked by a flattening of the real Phillips curve. Furthermore, the profit-led pattern appears to be even stronger than in the baseline model: technology shocks raise output up to the 6th quarter and raise employment up to the 7th quarter in the pre-1984 period, and have a positive effect on output and employment for seven quarters in the Great Moderation. In the latter, a wage shock also lowers employment in the first quarter. In addition, this model specification confirms the negative response of productivity to demand shocks at business cycle frequencies, probably due to the cleansing effects of recessions: in the pre-1984 period, productivity does not even show the one-quarter positive response to demand we found in the baseline model, and demand shocks lower productivity for five periods; after 1984, demand shocks harm productivity for seven quarters.

These results shed some doubt on the argument that the appearance of a profit-led/profit-squeeze pattern is the result of a failure to control for procyclical variation in labour productivity. Indeed, the effects of distributive and technology shocks on output and employment, as well as the distributional and productivity effects of changes in demand and employment, are broadly the same in both the baseline model, in which demand only has a lagged effect on labour productivity, and the robustness check model identified according to equation (16), in which productivity is contemporaneously affected by demand. Impulse responses support profit-led demand and employment in both subperiods and the disappearance of the cyclical profit squeeze in (e, ω) in the transition from the post-war period to the Great Moderation. Furthermore, the comovements of output and productivity are *negative* at business cycle frequencies conditional to demand shocks – a result which is fundamentally unaltered if we use the identification strategy in equation (16). However, differently from Mendieta-Muñoz, *et al.* (2021), we found that the profit-led pattern is largely driven by technology shocks, rather than distributive shocks, as the response of output and employment to increases in productivity is positive and persistent, whereas wage shocks have a one-quarter negative impact on employment. Thus, our results suggest that the negative comovements between economic activity and labour share in the initial phase of booms and recession do not reflect procyclical labour productivity, as in the argument of wage-led growth supporters, but still profit-led activity, although driven more by technology than distributive shocks.

[16] See Section 2 and Lavoie (2017).

8. CONCLUDING REMARKS

This paper empirically tested an extended version of the Goodwin model including aggregate demand and a decomposed labour share. It employed a structural vector autoregressive model identified by means of a non-recursive matrix of contemporaneous effects, with restrictions guided by classical-Keynesian and induced innovation theory. The whole period was split into two subperiods, the post-war period (1948-1984) and the Great Moderation (1985-2019), in order to illustrate the changes in the properties of the US business cycle. We then added to the debate and empirical evidence on the distributive cycle, induced innovation, and the changing pattern of cyclicality in the US labour productivity.

The Goodwin model and its subsequent developments predict counterclockwise cycles in the activity-labour share plane, as a result of the combination of profit-led activity and profit-squeeze distribution. The standard story focuses on the Marxian account of class conflict, resulting from the interaction of profit-constrained capital accumulation and employment-driven real wages. Our empirical findings confirm the existence of a profit-led/profit-squeeze pattern at business cycle frequencies during the post-war period. During the Great Moderation, the cyclical profit squeeze in the employment-distribution space appears to have been completely broken, in accordance with the view that neoliberal institutional changes succeeded in preventing wages from rising in economic upturns.

We have shown that the argument of procyclical labour productivity invoked by supporters of wage-led growth to question the existence or the source of the Goodwin pattern does not appear to be well-founded. Indeed, productivity comoves negatively with output at business cycle frequencies conditional to demand shocks, and the findings of profit-led demand and employment and profit-squeeze distribution are robust to allowing for a contemporaneous effect of demand on productivity. However, the profit-led pattern turned out to be largely driven by technology shocks, rather than distributive shocks, irrespective of the chosen identification strategy. Across almost all specifications, technology shocks had a positive and persistent effect on output and employment, whereas wage shocks only caused employment to fall for one or two quarters in the postwar period. The standard Marxian explanation of business cycle fluctuations then needs to be integrated with the consideration of the positive effects of technology on economic activity and employment.

The classical approach to induced innovation theory suggests that part of these economic fluctuations are the result of wage-led technology shocks, reflecting the capitalists' incentive to adopt labour-saving innovations in response to rising real wages. Our findings show that increases in real wages did indeed have a positive and persistent effect on labour productivity over the whole sample period, in line with the predictions of the theory.

Finally, we claimed that the changing pattern of cyclicality in the US labour productivity and the disappearance of the cyclical profit squeeze in the transition from the post-war period to the Great Moderation are consistent with the operation of distribution-induced technical change at business cycle frequencies. Our argument posits that distribution-induced innovation and the profit squeeze cause labour productivity to comove positively with output over the cycle. Causality goes from output to labour productivity via employment and real wages: in economic upturns, increases in labour market tightness allow workers to claim for higher real wages; capitalists try to counteract profit squeezing with higher investment in labour-saving innovations. The breakdown of the cyclical profit squeeze in the Great Moderation then accounts for part of the decline in the cyclical correlation between output and labour productivity. If labour-saving innovations are driven by increases in real wages, but the latter does not respond any longer to fluctuations in economic activity, labour productivity comoves less positively with output over the cycle. Impulse responses qualitatively support our story. The next advance in this line of investigation should quantify the contribution of the induced innovation channel relative to competing explanations of the changing cyclicality of

productivity.

Our results appear to indicate a promising avenue for future research on the interaction between changes in labour market institutions, the business cycle, and induced innovation. Previous contributions have investigated the long-run association between labour share and economic growth via the induced innovation channel. In this paper, we have drawn a further implication of the induced innovation theory for the cyclical behaviour of wages and productivity. A promising research agenda is to link short-run and long-run effects of distributive shocks and jointly investigate the impact of institutional changes on the properties and the structural shifts of the business cycle. This analysis is left for future work.

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APPENDIX A

Tab. A1. *Data description and data source*

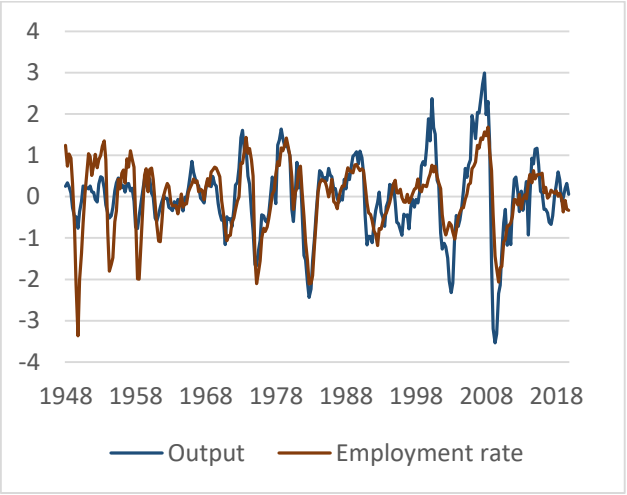
Y_t	Output of the business sector: "Business Sector: Output for All Employed Persons, Index 2012=100, Quarterly, Seasonally Adjusted" ("OUTBS" series), retrieved from Federal Reserve Bank of St. Louis Economic Database (FRED). Output of the nonfarm business sector: "Nonfarm Business Sector: Output for All Employed Persons, Index 2012=100, Quarterly, Seasonally Adjusted" ("OUTNFB" series), retrieved from Federal Reserve Bank of St. Louis Economic Database (FRED). GDP: "Real Gross Domestic Product, Billions of Chained 2012 Dollars, Quarterly, Seasonally Adjusted Annual Rate" ("GDPC1" series), computed as index 2012=100 and retrieved from Federal Reserve Bank of St. Louis Economic Database (FRED). Output gap, measured as the difference between actual GDP and potential GDP, where actual GDP is "Real Gross Domestic Product, Billions of Chained 2012 Dollars, Quarterly, Seasonally Adjusted Annual Rate" ("GDPC1" series) and potential GDP is "Real Potential Gross Domestic Product, Billions of Chained 2012 Dollars, Quarterly, Not Seasonally Adjusted" ("GDPPOT" series), both indexed relative to 2012 levels of potential GDP (index 2012 = 100) and retrieved from Federal Reserve Bank of St. Louis Economic Database (FRED). The potential GDP series starts from 1949.
e_t	Employment rate, measured as 100 minus "Unemployment Rate, Percent, Monthly, Seasonally Adjusted" ("UNRATE" series), retrieved from Federal Reserve Bank of St. Louis Economic Database (FRED). Employment levels in the business sector: "Business Sector: Employment for All Employed Persons, Index 2012=100, Quarterly, Seasonally Adjusted" ("PRS84006013" series), retrieved from Federal Reserve Bank of St. Louis Economic Database (FRED). Hours worked in the nonfarm business sector: "Nonfarm Business Sector: Hours Worked for All Employed Persons, Index 2012=100, Quarterly, Seasonally Adjusted" ("HOANBS" series), retrieved from Federal Reserve Bank of St. Louis Economic Database (FRED).
w_t	Real wages in the business sector: "Business Sector: Real Hourly Compensation for All Employed Persons, Index 2012=100, Quarterly, Seasonally Adjusted" ("RCPHBS" series), retrieved from Federal Reserve Bank of St. Louis Economic Database (FRED). Real wages in the nonfarm business sector: "Nonfarm Business Sector: Real Hourly Compensation for All Employed Persons, Index 2012=100, Quarterly, Seasonally Adjusted" ("COMPRNFB" series), retrieved from Federal Reserve Bank of St. Louis Economic Database (FRED).
a_t	Labour productivity in the business sector: "Business Sector: Labor Productivity (Output per Hour) for All Employed Persons, Index 2012=100, Quarterly, Seasonally Adjusted" ("OPHPBS" series), retrieved from Federal Reserve Bank of St. Louis Economic Database (FRED). Labour productivity in the nonfarm business sector: "Nonfarm Business Sector: Labor Productivity (Output per Hour) for All Employed Persons, Index 2012=100, Quarterly, Seasonally Adjusted" ("OPHNFB" series), retrieved from Federal Reserve Bank of St. Louis Economic Database (FRED).

In the baseline and all robustness check models we used detrended data, applying the Hodrick-Prescott filter, with a standard smoothing parameter for quarterly data ($\lambda = 1600$). All HP-filtered series are $I(0)$.

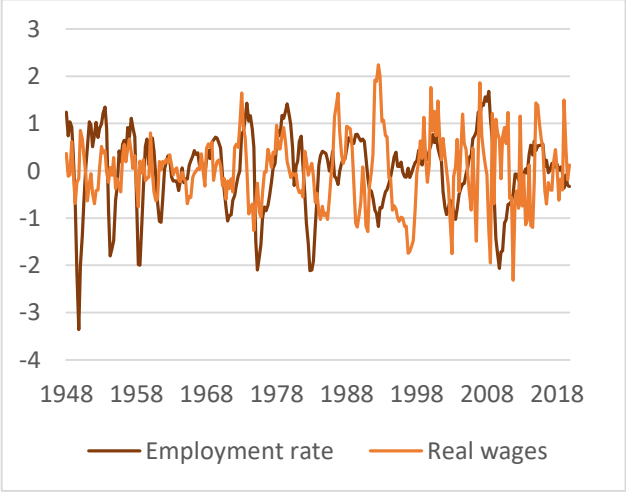
APPENDIX B

Fig. B1. *Cyclical fluctuations in output, labour productivity, real wages, and employment rate*

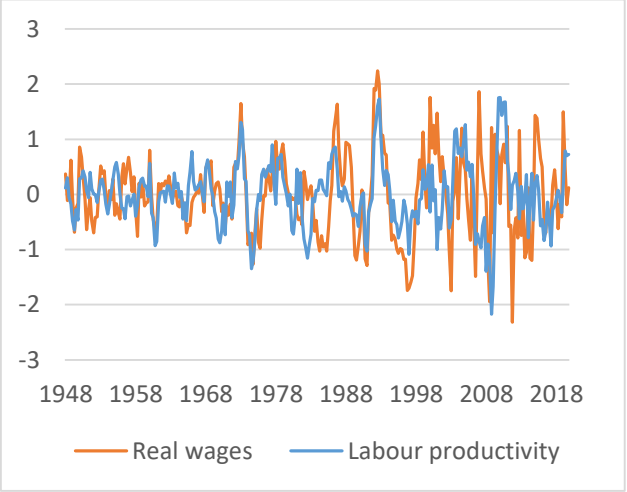
a) Output and labour productivity



b) Output and employment rate



c) Employment rate and real wages



d) Real wages and labour productivity

Notes: The series refer to the US business sector. Data are detrended using the HP filter with smoothing parameter λ=1600.

Tab. B1. *Changes in volatility of employment levels and hours worked*

	Absolute SD		SD relative to employment	
	Pre-1984	Post-1984	Pre-1984	Post-1984
Raw series				
Employment				
Business	9.175317	9.246799	–	–
Nonfarm business	10.727918	9.647619	–	–
Hours				
Business	7.579660	8.347409	0.826092	0.902735
Nonfarm business	9.346647	8.671981	0.871245	0.898873
HP filter				
Employment				
Business	0.980436	1.320809	–	–
Nonfarm business	0.979008	1.335022	–	–
Hours				
Business	1.264283	1.602440	1.289511	1.213226
Nonfarm business	1.252784	1.617608	1.279646	1.211671

APPENDIX C

Tab. C1. *Augmented Dickey-Fuller unit root test statistics for the cyclical components of output, employment rate, real wages, and labour productivity (baseline model)*

	Intercept	Intercept and trend
Output (Y_t)	– 6.499597**	– 6.488036**
Employment rate (e_t)	– 8.092636**	– 8.081474**
Real wages (w_t)	– 6.861069**	– 6.848849**
Labour productivity (a_t)	– 6.815739**	– 6.801450**

*Notes: ** = significant at the 1% level. ADF tests include 2 lags.*

Tab. C2. *VAR lag length selection criteria (baseline model)*

Lag	FPE	AIC	SC	HQ
Pre-1984				
0	0.002695	5.435030	5.519077	5.469184
1	4.73e-05	1.391329	1.811563*	1.562100
2	3.47e-05*	1.082895*	1.839317	1.390282*
3	3.72e-05	1.149421	2.242031	1.593425
4	4.11e-05	1.247504	2.676302	1.828125
5	4.75e-05	1.387789	3.152775	2.105027
6	5.15e-05	1.461966	3.563139	2.315820
7	5.73e-05	1.559686	3.997046	2.550156
8	5.33e-05	1.476014	4.249563	2.603102
Post-1984				
0	0.014688	7.130766	7.214813	7.164920
1	0.000276	3.155894	3.576128*	3.326665
2	0.000208*	2.872910*	3.629333	3.180298*
3	0.000219	2.923781	4.016391	3.367785
4	0.000251	3.057613	4.486410	3.638233
5	0.000284	3.175610	4.940595	3.892847
6	0.000311	3.261685	5.362858	4.115568
7	0.000330	3.312166	5.749527	4.302636
8	0.000331	3.301221	6.074770	4.428308

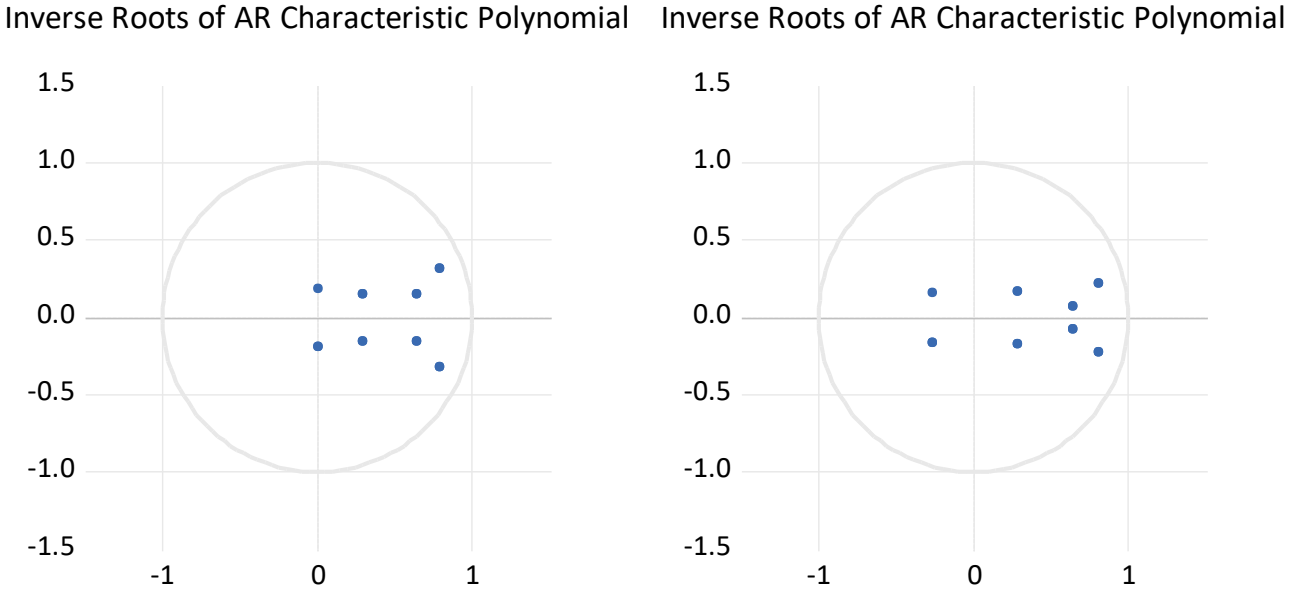
*Notes: * = lag order selected by the criterion. FPE: Final prediction error, AIC: Akaike information criterion, SC: Schwarz information criterion, HQ: Hannan-Quinn information criterion.*

Tab. C3. *VAR residual serial correlation LM tests (baseline model)*

Lag	LRE stat	Prob.
Pre-1984		
1	15.62607	0.4793
2	17.90339	0.3296
3	15.02220	0.5230
4	16.36751	0.4276
5	9.427065	0.8948
6	8.896066	0.9176
7	9.049141	0.9114
8	38.19065	0.0014
Post-1984		
1	19.61934	0.2379
2	14.08253	0.5926
3	14.23156	0.5815
4	14.58374	0.5553
5	23.00201	0.1137
6	9.987885	0.8673
7	18.27798	0.3079
8	39.68883	0.0009

Note: *LRE: Edgeworth expansion corrected likelihood ratio.*

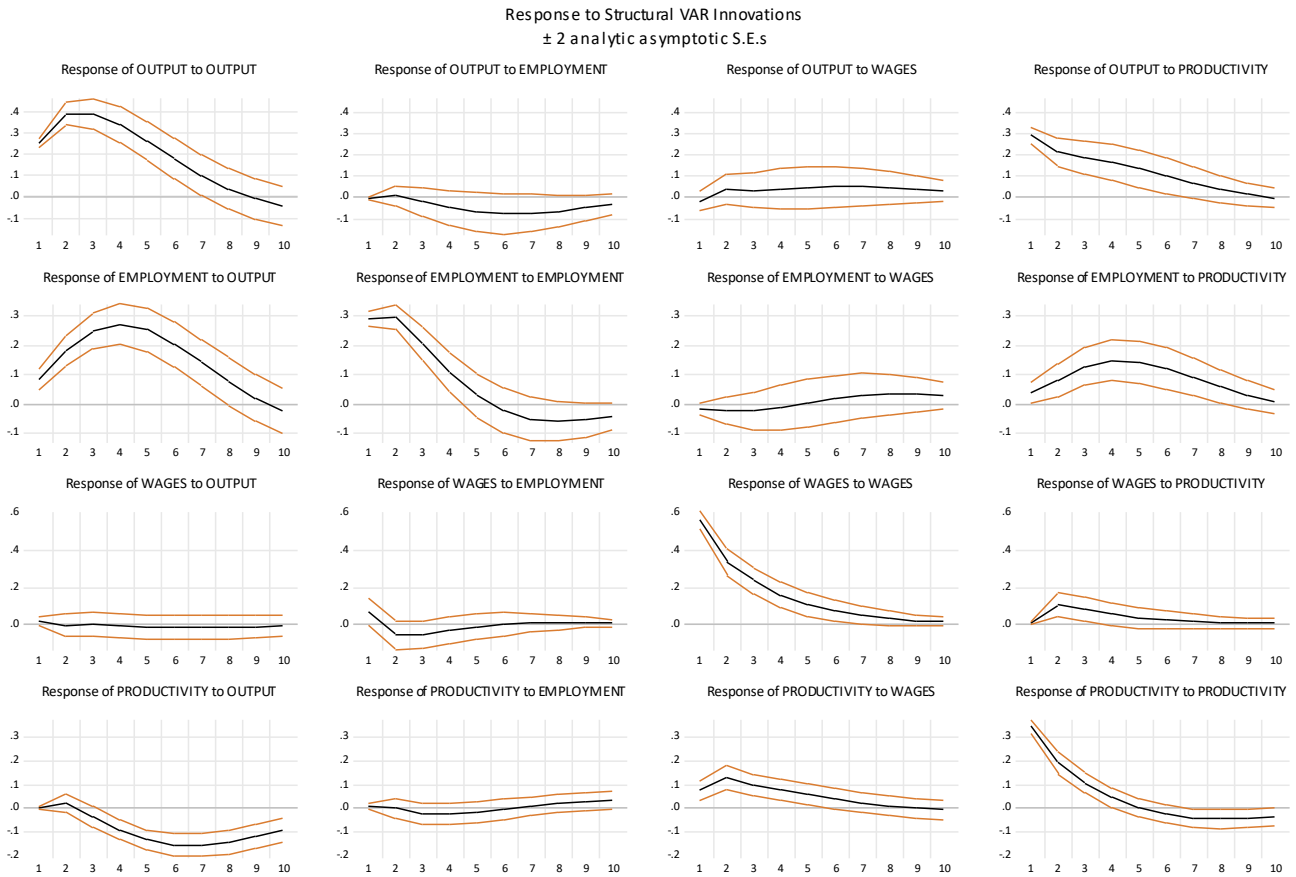
Fig. C1. *VAR stability conditions (baseline model)*



a) Pre-1984 *b) Post-1984*

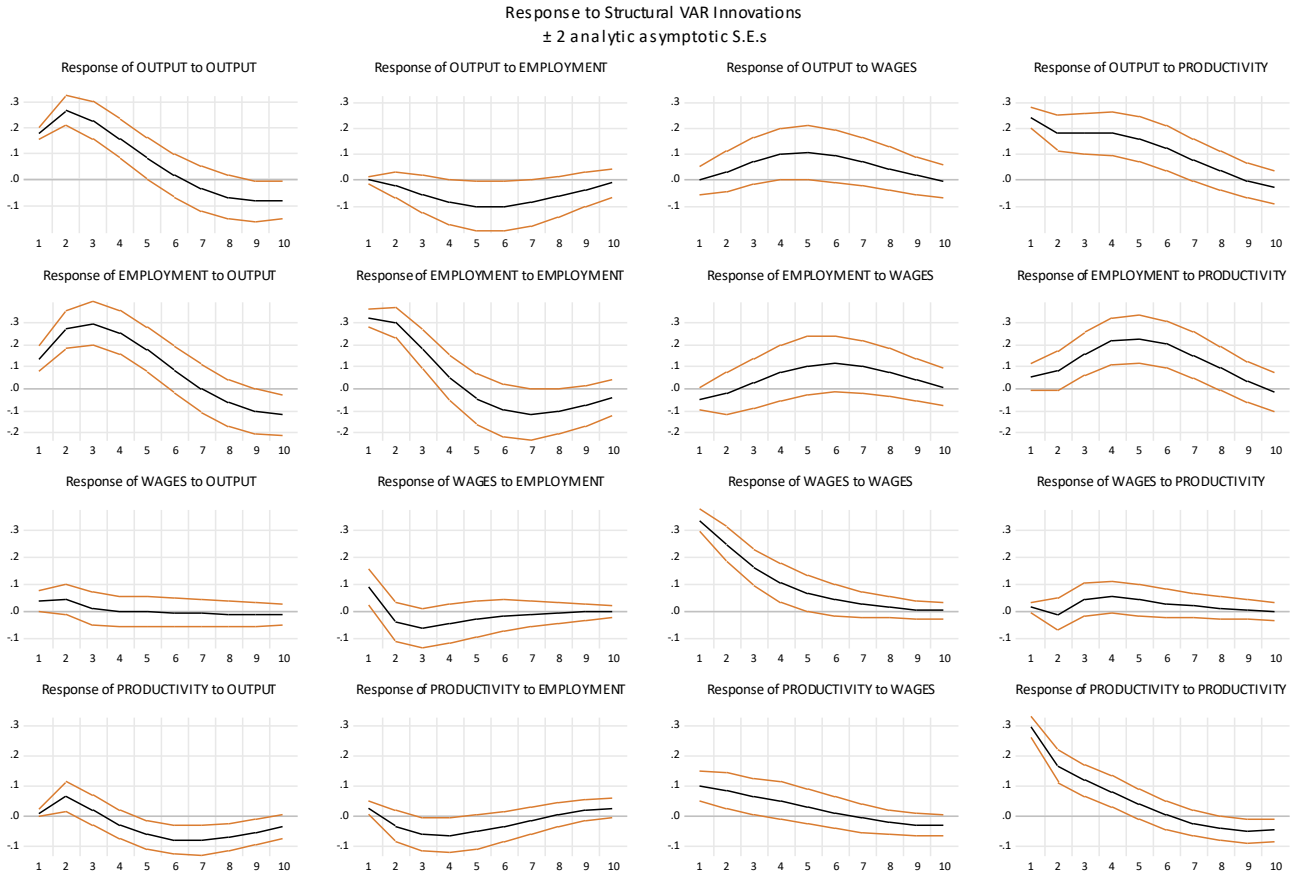
APPENDIX D

Fig. D1. *Impulse response functions, baseline model*

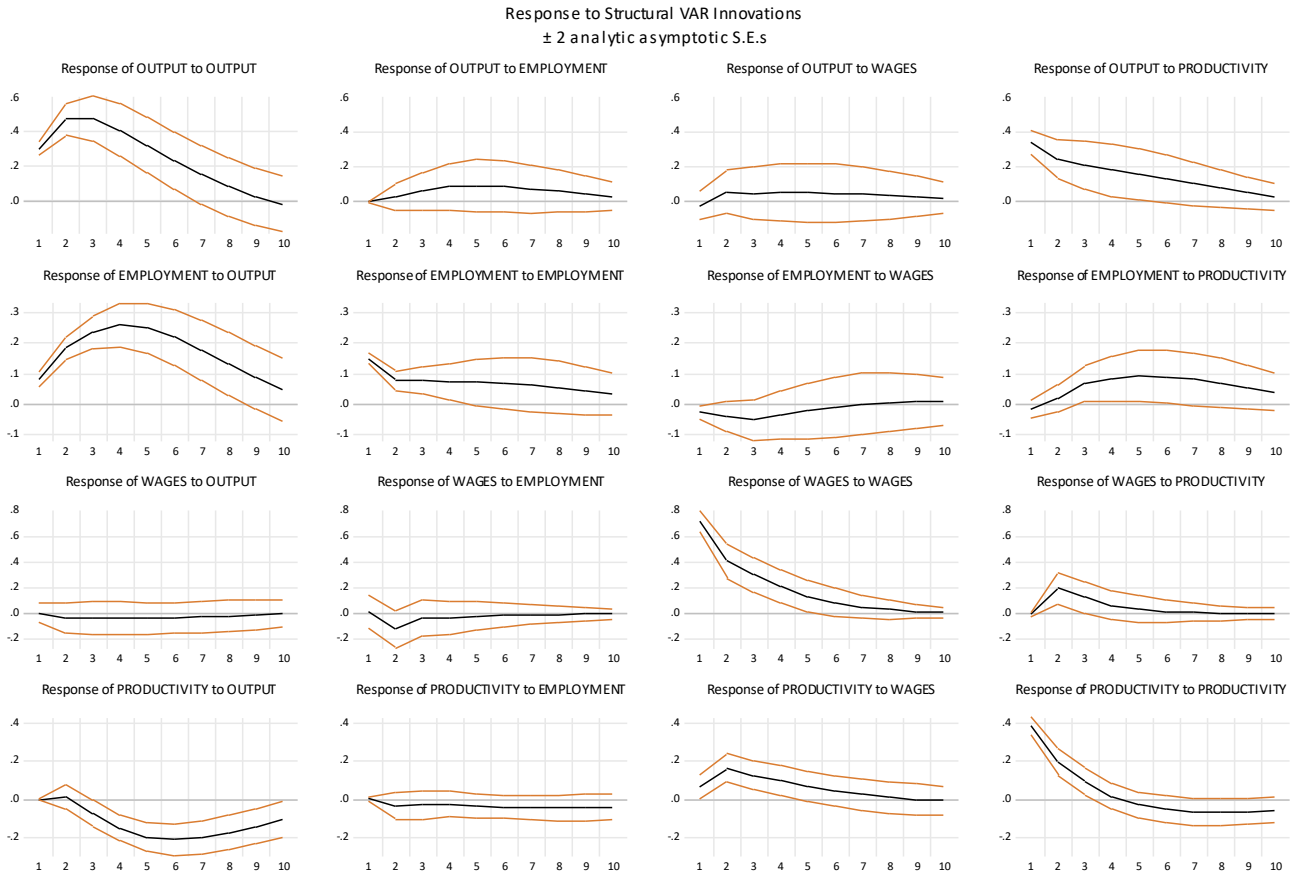


a) 1948-2019

Fig. D1. *(continued)*

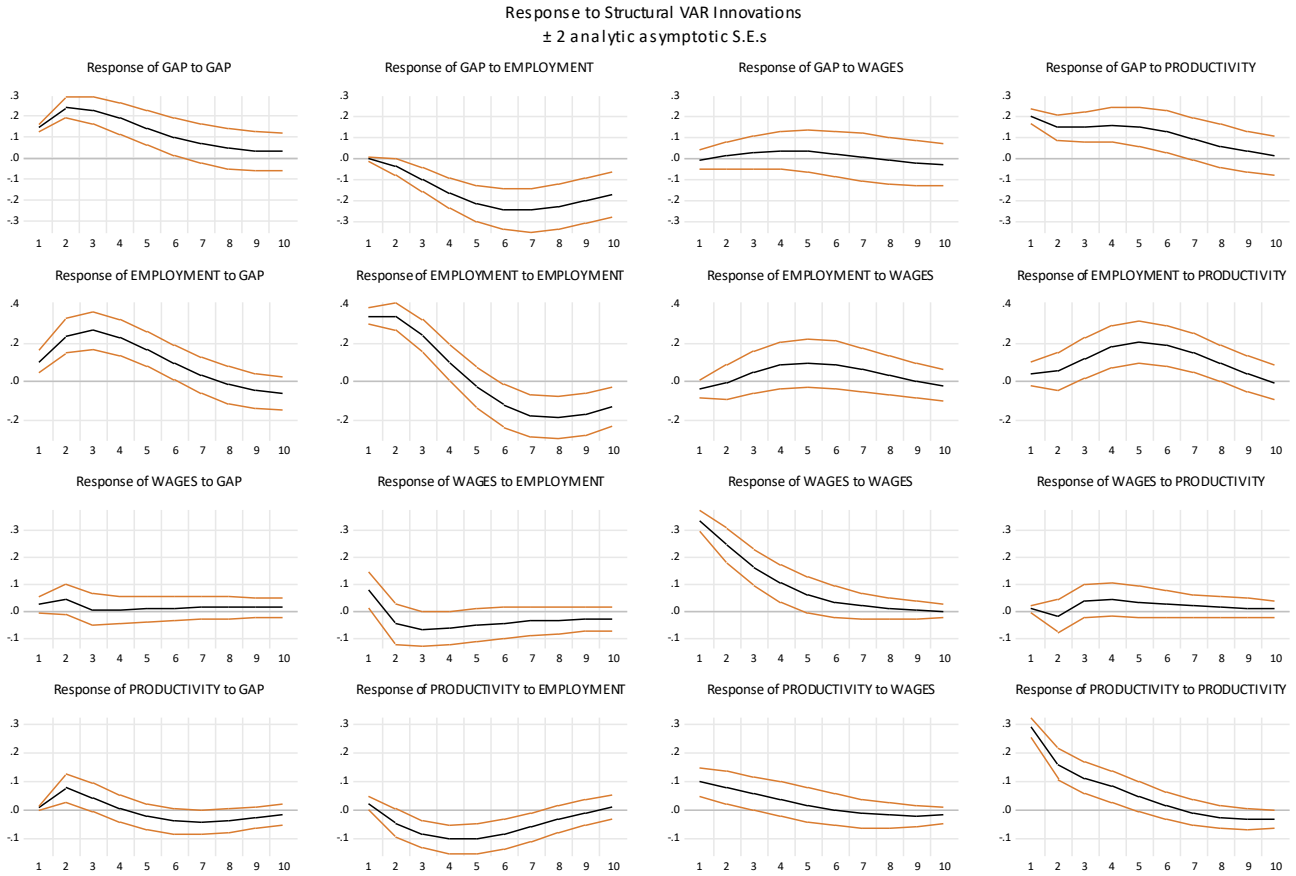


b) Pre-1984

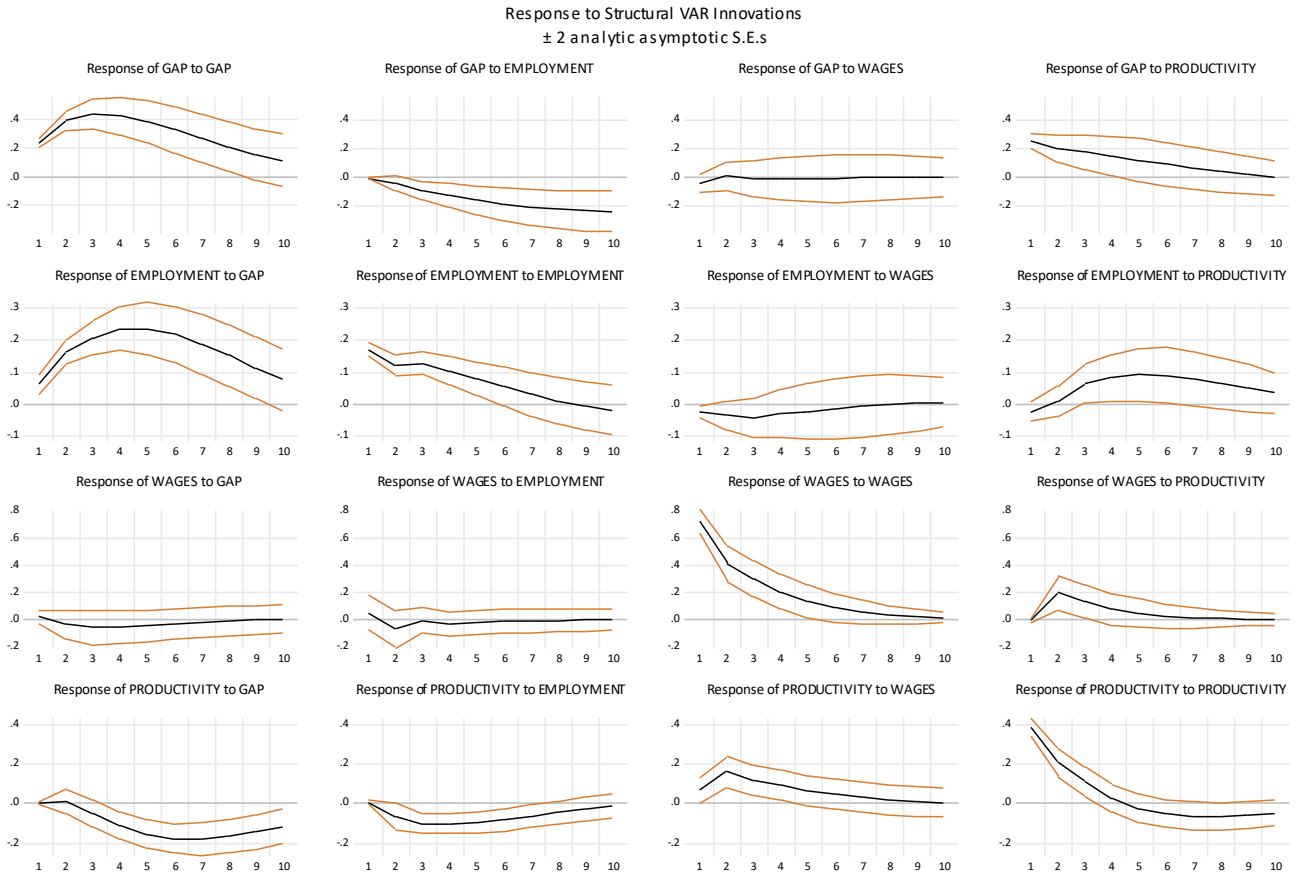


c) Post-1984

Fig. D2. *Impulse response functions, robustness check model 1 (output gap)*

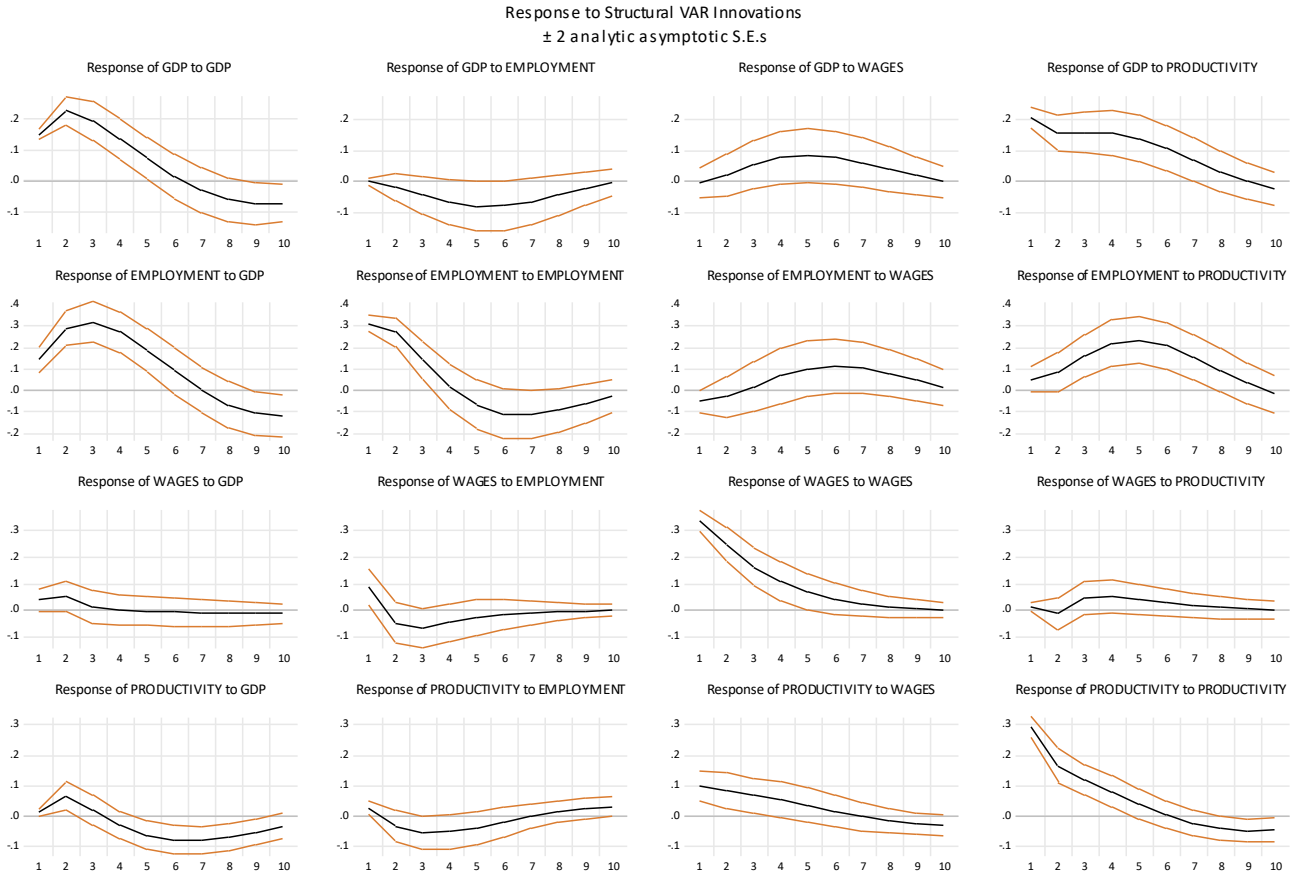


a) Pre-1984

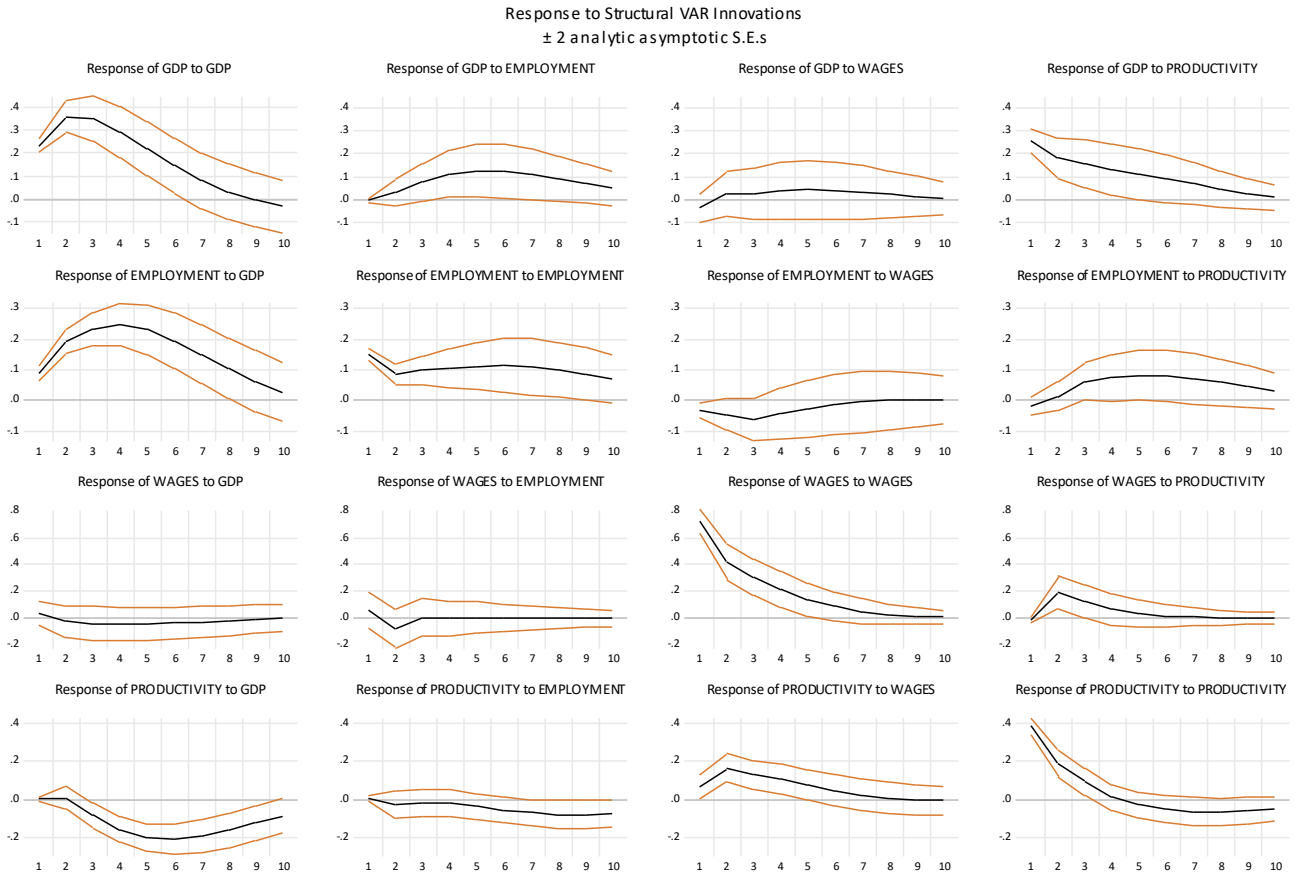


b) Post-1984

Fig. D3. *Impulse response functions, robustness check model 2 (GDP)*

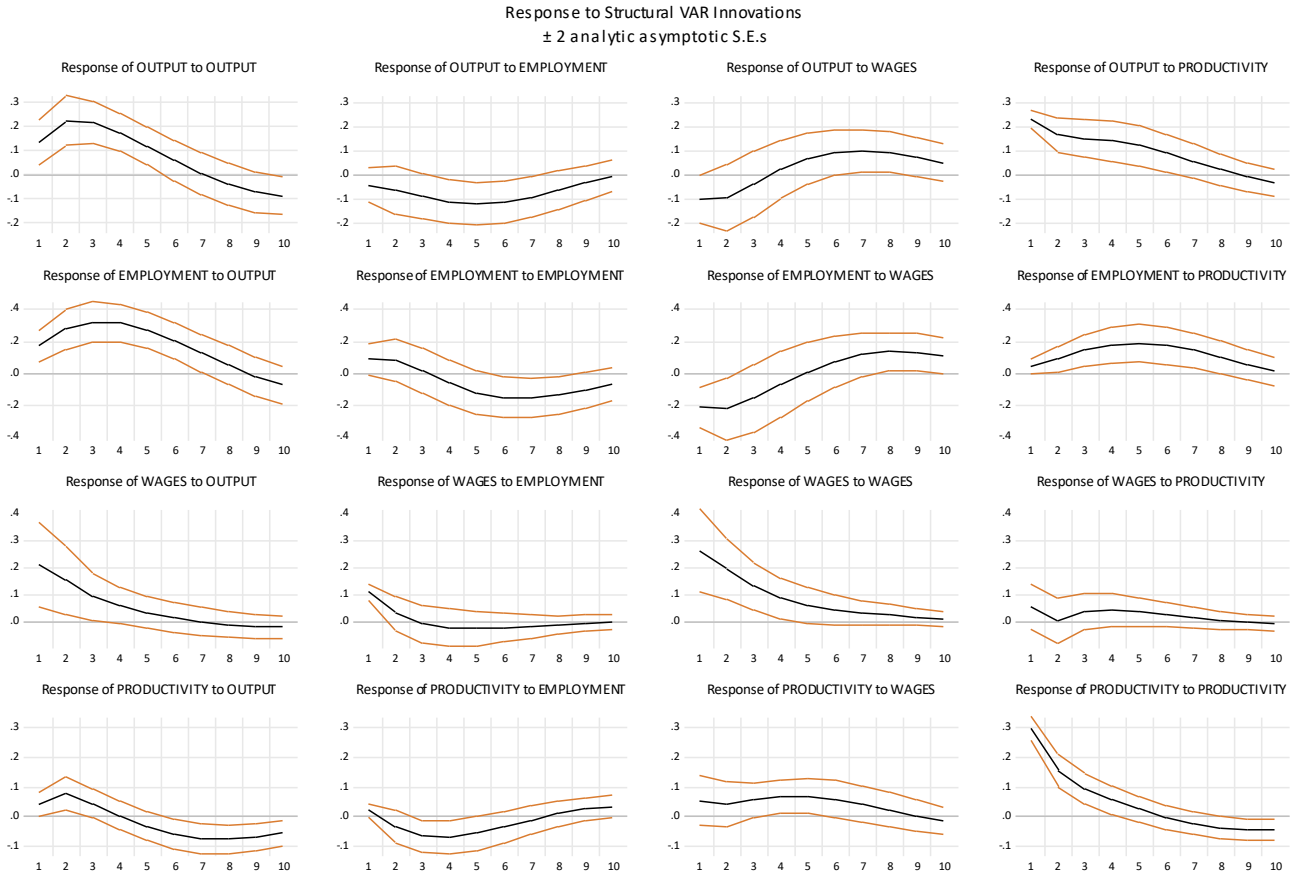


a) Pre-1984

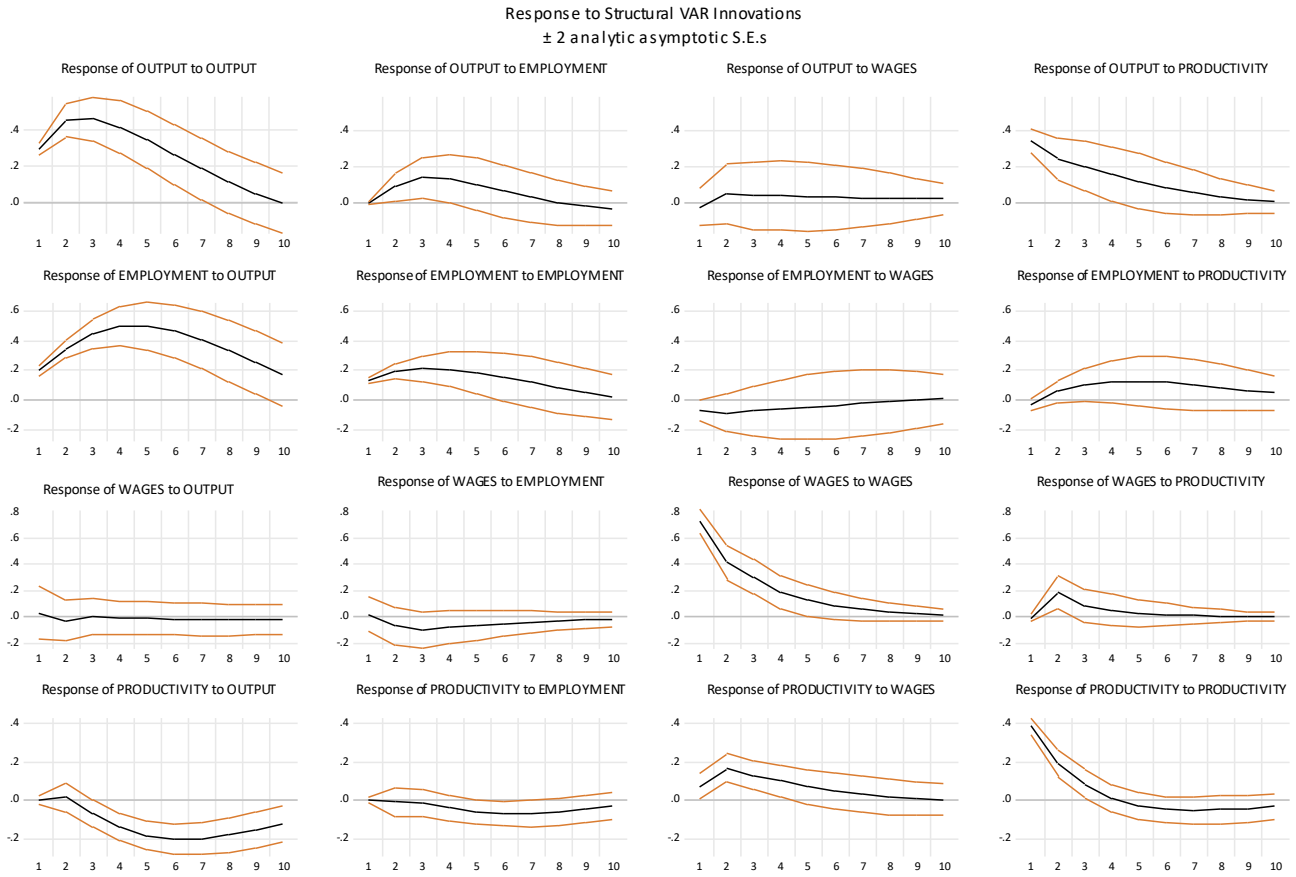


b) Post-1984

Fig. D4. *Impulse response functions, robustness check model 3 (employment level)*

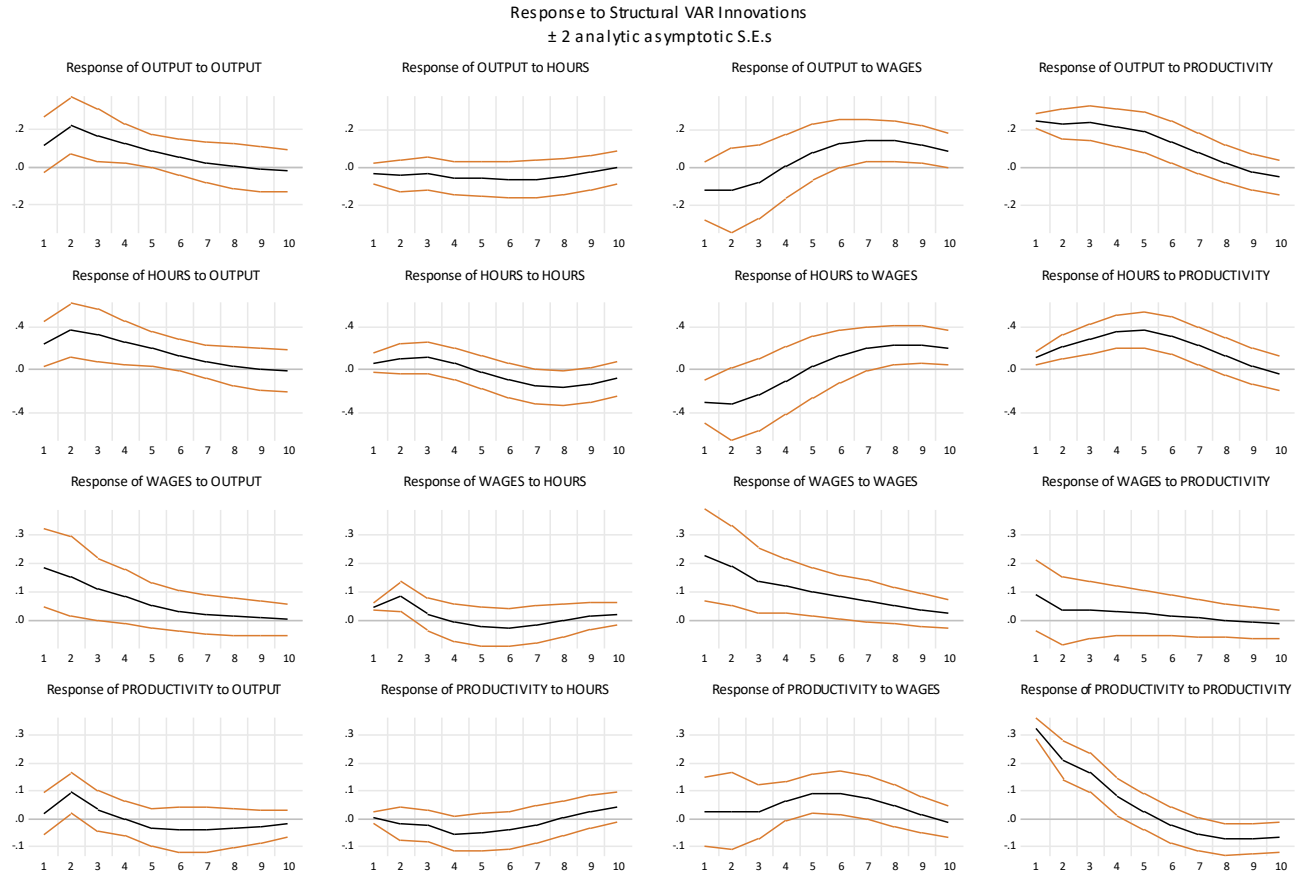


a) Pre-1984

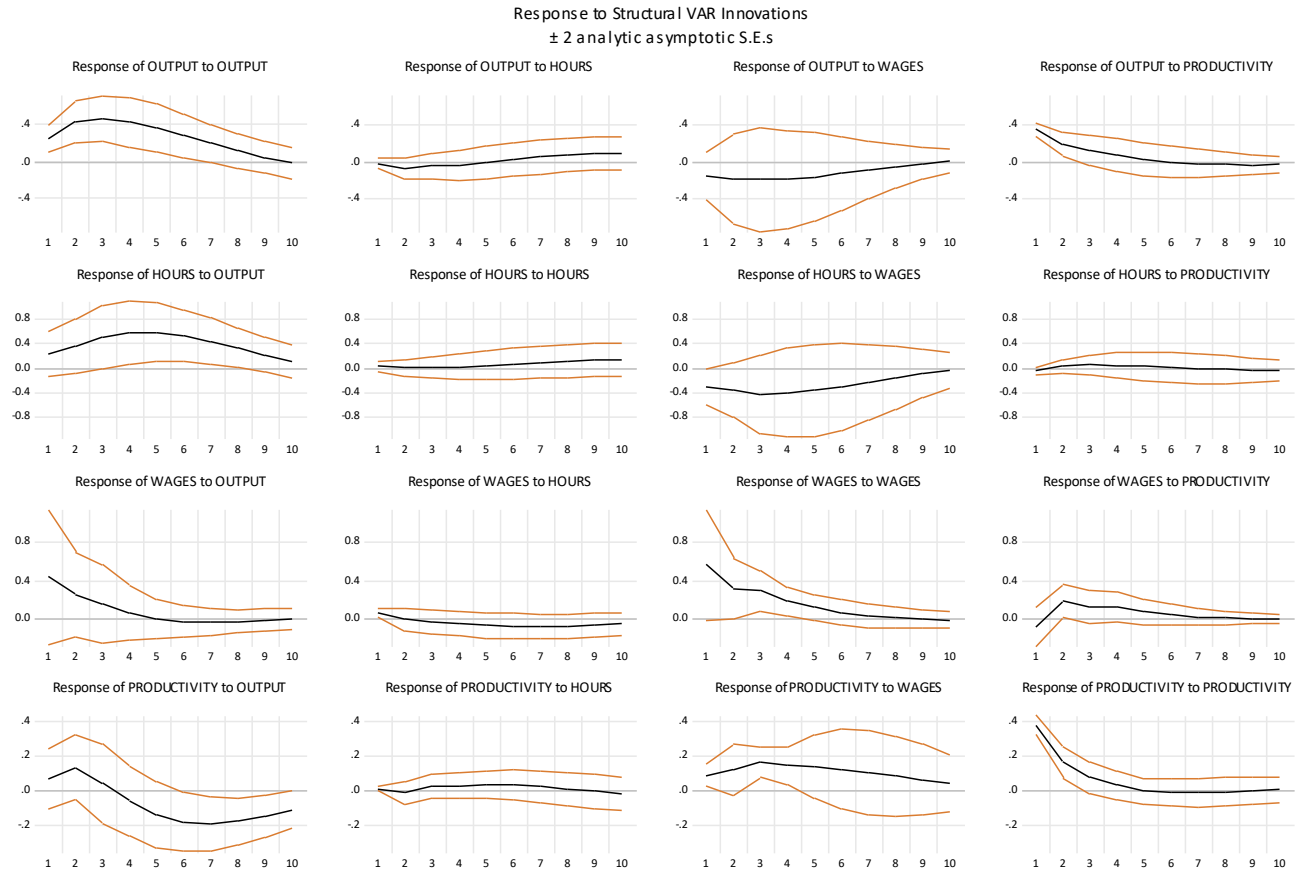


b) Post-1984

Fig. D5. *Impulse response functions, robustness check model 4 (hours worked, nonfarm business)*

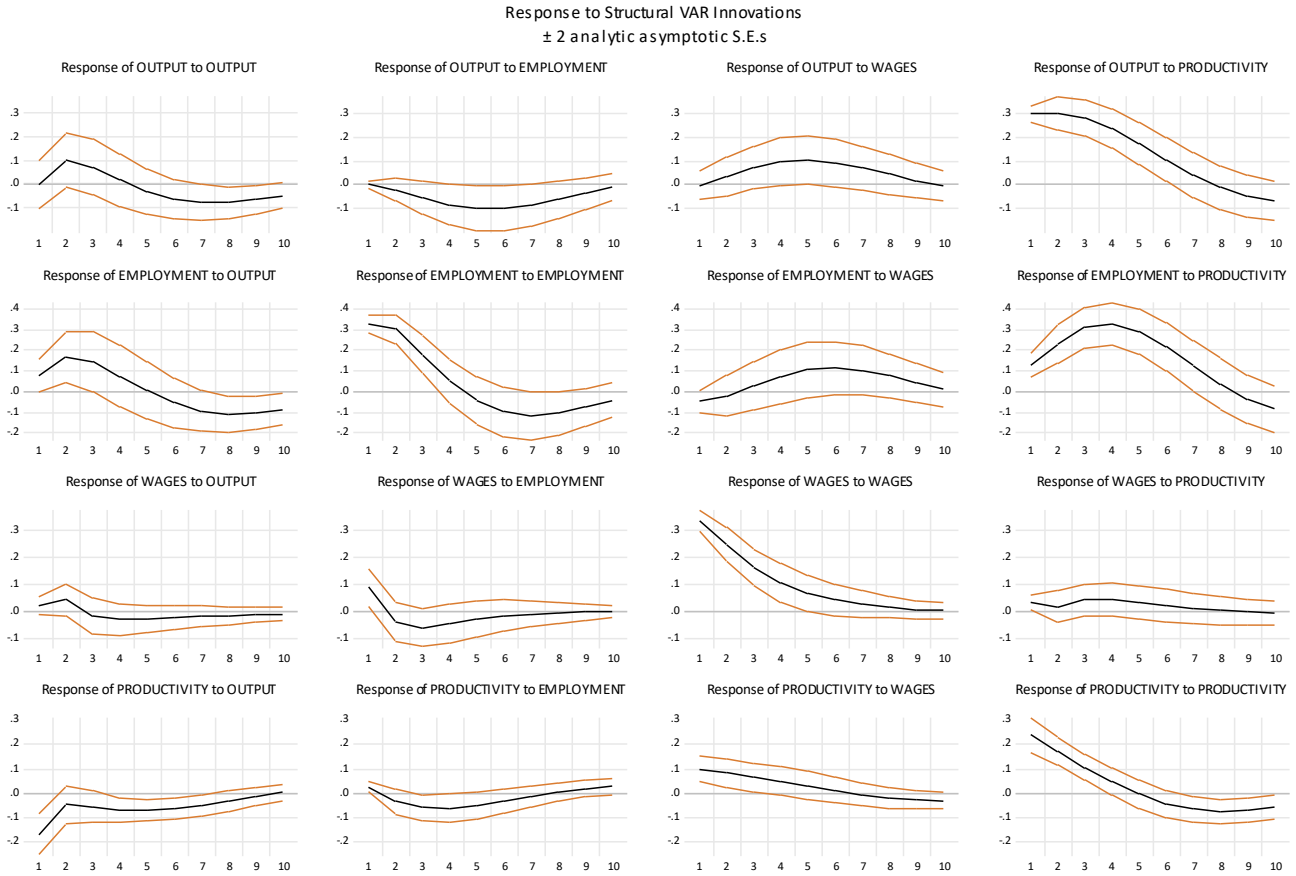


a) Pre-1984

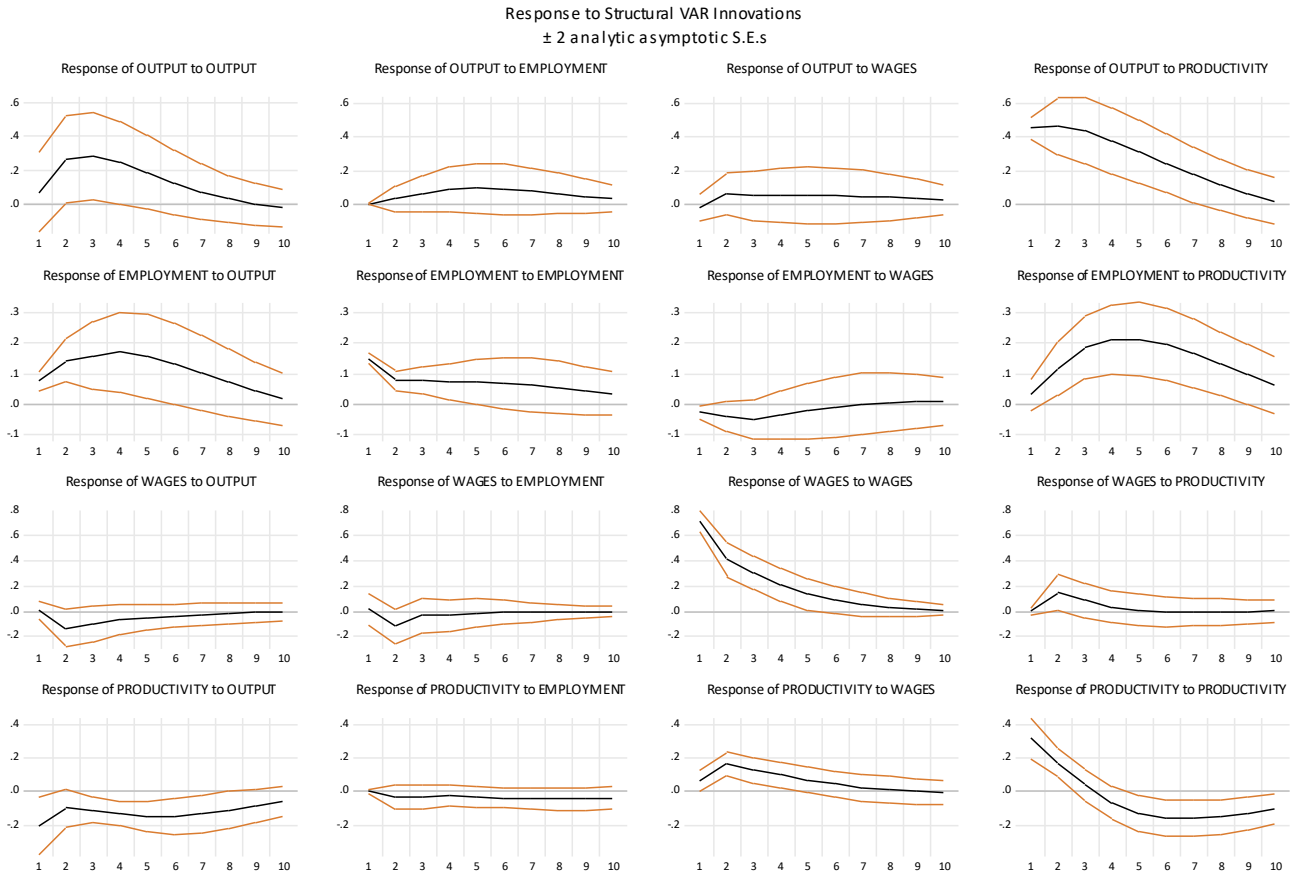


b) Post-1984

Fig. D6. *Impulse response functions, robustness check model 5 (alternative identifying restrictions)*



a) Pre-1984



b) Post-1984